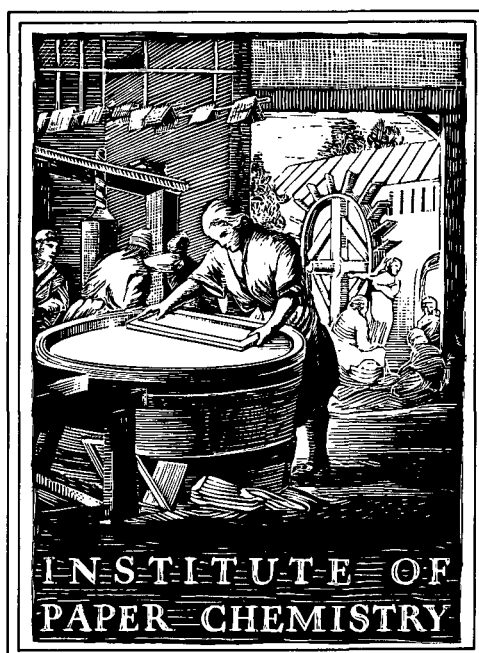


PROJECT ADVISORY COMMITTEE

Subcommittee on
Systems Analysis



IPC STAFF STATUS REPORTS

This information represents a review of on-going research for use by the Project Advisory Subcommittees. The information is not intended to be a definitive progress report on any of the projects and should not be cited or referenced in any paper or correspondence external to your company.

Your advice and suggestions on any of the projects will be most welcome.

FOR MEMBER COMPANIES ONLY

NOTICE & DISCLAIMER

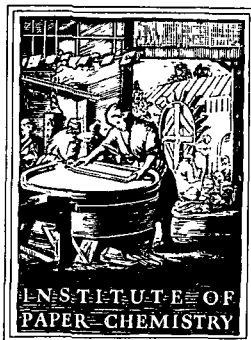
The Institute of Paper Chemistry (IPC) has provided a high standard of professional service and has exerted its best efforts within the time and funds available for this project. The information and conclusions are advisory and are intended only for the internal use by any company who may receive this report. Each company must decide for itself the best approach to solving any problems it may have and how, or whether, this reported information should be considered in its approach.

IPC does not recommend particular products, procedures, materials, or services. These are included only in the interest of completeness within a laboratory context and budgetary constraint. Actual products, procedures, materials, and services used may differ and are peculiar to the operations of each company.

In no event shall IPC or its employees and agents have any obligation or liability for damages, including, but not limited to, consequential damages, arising out of or in connection with any company's use of, or inability to use, the reported information. IPC provides no warranty or guaranty of results.

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Your advice and suggestions on any of the projects will be most welcome.



THE INSTITUTE OF PAPER CHEMISTRY

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March 6, 1989

TO: Members of the Systems Analysis Project Advisory Committee

Enclosed is advance reading material for the March 28-29 meeting of the Systems Analysis Project Advisory Committee. Included is the status report, an agenda, and a current committee membership list.

Rooms have been reserved in the Continuing Education Center, and meals will be provided as stated on the agenda. If you haven't already indicated your attendance, please do so at your earliest convenience by returning your registration form or calling Jennifer Schuh at 414/738-3320. Also enclosed is the Security Card with the number to gain entrance into the Continuing Education Center.

For all Project Advisory Committee meetings, the Institute invites its member companies to send one or more representatives to attend the review sessions (first day) of any or all of the meetings. PAC members from member companies are also welcome to attend the other meetings, and may stay in the CEC and attend meetings and meals of their choice, at no cost. If you wish to attend any of the other meetings, but haven't registered, please call Jennifer Schuh to do so. A meeting schedule is enclosed for your information.

We look forward to meeting with you on March 28-29.

Sincerely,

Ronald A. Yeske
Vice President
Research and Academic Affairs

RAY/lms
Enclosures

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Appendix II - Student Paper Contest

AGENDA

SYSTEMS ANALYSIS PROJECT ADVISORY COMMITTEE MEETING

The Institute of Paper Chemistry
Continuing Education Center
Appleton, Wisconsin

Tuesday, March 28, 1989

12:00-1:00	Lunch (CEC Dining Room)	
1:00-1:15	Introductory Remarks	Jim Bonner
1:15-1:30	Atlanta Relocation Plans	
1:30-2:00	MAPPS Status Report	Jim Rushton
2:00-2:15	MAPPS Executive/Interface	Mike Schreiter
2:15-2:30	Break	
2:30-3:30	Performance Attribute Modeling	Gary Jones
3:30-4:00	DOE Proposal	Gary Jones
4:00-5:00	Development Issues	Jim Rushton
5:00-5:30	Student Work/MAPPS Courses/ Other Simulation Efforts	Gary Jones
5:30-6:00	Cocktails	
6:00	Dinner	
7:00	*MAPPS Users Group Meeting	Jack Landin

Wednesday, March 29, 1989

7:00-8:00	Breakfast (CEC Dining Room)	
8:00	Committee Review Session (small conference room, CEC)	PAC Committee
8:30-12:00	MAPPS Users Group Meeting (large conference room, CEC)	

*Users Group will meet with Committee and IPC staff during the afternoon of March 28.

SYSTEMS ANALYSIS

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2/89

*date of retirement

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

Status Report
to the
SYSTEMS ANALYSIS
PROJECT ADVISORY COMMITTEE

Project 3471
PROCESS MODELING AND SIMULATION

March 28-29, 1989

THE INSTITUTE OF PAPER CHEMISTRY

Project Advisory Committee Spring Meetings
Member Dues-Funded Research Reviews

March 21, 22, 23, 28, and 29

1989

Continuing Education Center
Appleton, Wisconsin
(414) 734-9251

<u>Committee</u>	<u>Review Schedule</u>	<u>Research Area*</u>
Pulping Processes	Tuesday, March 21 8:30 a.m. - 5:30 p.m. Dinner at 6:00 p.m.	Kraft Chemical Recovery Furnace Processes Chemical Pulp Alkali Pulping Oxygen Bleaching Chlorinated Organics Analytical Techniques Microstructure of Wood Fibers High Lignin Pulp Photochemistry
Paper Properties	Wednesday, March 22 8:30 a.m. - 5:30 p.m. Dinner at 6:00 p.m.	Board Properties and Performance Process, Properties, Product Relationships Internal Strength Enhancement Strength Improvement and Failure Mechanisms On-line Measurement of Paper Mechanical Properties Fundamentals of Paper Surface Wettability
Engineering	Thursday, March 23 10:00 a.m. - 5:30 p.m. Dinner at 6:00 p.m.	Corrosion Recovery Boiler Fireside Corrosion Kraft Liquor Corrosivity Suction Roll Failures Papermaking Displacement Pressing Wet Pressing Impulse Drying

**Not in order of agenda*

<u>Committee</u>	<u>Review Schedule</u>	<u>Research Area*</u>
Systems Analysis	Tuesday, March 28 1:00 p.m. - 5:30 p.m. Dinner at 6:00 p.m.	MAPPS Marketing Strategy MAPPS Simulator Development Continuing System Development Performance Attribute Modeling Optimization with MAPPS MAPPS Applications and Field Experience
Forest Biology	Wednesday, March 29 1:00 p.m. - 5:00 p.m. Dinner at 6:00 p.m.	Softwood Somatic Embryogenesis Initiation Development/Maturation Conversion Biochemistry of Embryo Development Hardwood Cloning

PROJECT SUMMARY FORM

DATE: March 28, 1989

PROJECT NO: 3471 - Process Modeling and Simulation

PROJECT LEADER: James D. Rushton

IPC GOAL:

To develop and support a marketable computer modelling capability covering the full spectrum of mill types and problems of interest to the Institute staff and to companies associated with the pulp and paper industry.

OBJECTIVE:

To develop a program for and to support the process simulation requirements of IPC member and associate member companies; to offer a competitively priced process simulation program to non-member companies on a fee basis to partially support the budget requirements of the Procass Modeling and Simulation Group.

CURRENT FISCAL BUDGET: \$ 150,000

SUMMARY OF RESULTS SINCE LAST REPORT: October, 1988 - March, 1989**Personnel**

At the last PAC meeting, we reported on efforts to find a replacement for the Process Modeling and Simulation Group secretary by employing a "Micro Computer Support Technician." Before this position was filled, Mary Berceau resigned her half-time position as Assistant Engineer with the MAPPS Group. Although we hope that Mary will be able to work a few hours per week offsite developing a functional specification for the new executive interface, we have lost a considerable portion of her time. Mike Schreiter is still with us, but, unfortunately, he has made the decision not to make the move to Atlanta.

We are pleased to announce that Rex Skifstad has been appointed to a position as Micro-computer Support Technician for the Group. Rex's wife also works in the Library at IPC and they plan to re-locate to Atlanta with us.

A proposal has also been submitted to the Department of Energy for a long term case study involving two millwide process simulations. If accepted, this proposal will significantly increase personnel requirements for the Group. As you can see, we will have a number of positions to fill after we move to Atlanta. Please contact us if you have any candidates to recommend for any of these positions.

New User

Since the last reporting period, we have added one Member Company, Macmillan Bloedel Inc. and four academic institutions as users. The academic users are Universite du Quebec a Trois-Rivieres, Tuskegee University, the University of Wisconsin-Green Bay, and the University of Minnesota. Information on licensing MAPPS has also been sent to several international institutions, one private company, and a governmental agency but these contacts have, to date, not shown any further interest.

Meetings And Papers

Gary Jones has been very busy preparing papers on PAT Modeling for a number of technical society meetings.

The repulping application described above will be presented at the 1988 TAPPI Contaminant Problems & Strategies in Wastepaper Recycling Seminar April 24-26 in Madison, WI.

A synopsis of the performance attributes overview document will be

presented at the PIMA/MIS International Conference to be held April 19-21 in Cincinnati, OH. The paper, entitled "New Directions in Process Simulation", outlines our new approach to simulation using performance attributes and contrasts it with the traditional approach. Several applications are discussed and the benefits of PAT modelling are enumerated.

Portions of the newsprint mill simulation will be presented at the TAPPI Engineering Conference in September in Atlanta. This paper is one of two sponsored by the Process Simulation Committee as part of a joint session with the Process Engineering Committee on Product Quality Modelling and Simulation. The IPC paper will compare and contrast the model predictions and mill data and show the predicted effects of varying the stone groundwood content on machine paper properties and runnability. The other quality modelling paper will be presented by Lou Edwards.

A second IPC paper will be presented at the TAPPI Engineering Conference in the session on fluid mechanics. The paper describes the simulation of flow and turbulence in an experimental manifold currently under study at Beloit. This work is a follow-up of earlier work done describing the computational fluid mechanics of the headbox completed in 1988, presented at the 1988 TAPPI engineering conference in Chicago. It is discussed further in the section on Student Work.

All four of the above reports will be issued as IPC technical paper series reports.

A demonstration of the current status of Gary's PAT Models was also conducted for the TAPPI Process Simulation Steering Committee meeting held at the Continuing Education Center on February 1 - 2, 1989.

BUSINESS PLANNING AND MARKETING ACTIVITIES

Since January 3, a considerable amount of time has been devoted to business planning and marketing activities. With the current version of MAPPS, the key issue to consider when exploring opportunities to expand the market is the development of a new pricing strategy. A micro computer pricing option must be implemented to make MAPPS more competitive with the pricing options used by competing simulation program developers. Other important issues are finding new methods to publicize MAPPS, new releases of MAPPS (PAT's and executive/interactive interface), development of new products (dynamic simulator), and identification of new strategies to expand the consulting or contract services of the Group.

Micro Computer Pricing Options

The current pricing structure for licensing MAPPS source code is very favorable for member companies of the Institute and, to a lesser extent, associate member companies. However, the non-member category may be out of reach for many small pulp and paper related companies such as independent consultants, consulting engineering firms, and small-to-medium sized supplier companies. Also, many larger firms may not be willing to justify, without prior simulation experience, spending \$ 25,000 for MAPPS. A significant number of these companies probably would not have the personnel resources, the time, or desire to study or modify source code and would prefer to "stick with what they know" once they have it. For this market, a lower cost compiled micro computer version of MAPPS (copy-protected and licensed for single machine use), specifically designed to model limited pulp and paper operations, could be an attractive option. Thus, licensing options for several categories of compiled, copy-protected micro versions of MAPPS, priced according to IPC membership status, will be offered. The preliminary pricing of these options is as follows:

	Single Copy	Second Copy	Add. Copies (Each)
MEMBER COMPANY			
Chemical Pulping and Recovery	\$ 2,000	1,000	500
High Yield Pulping	1,500	750	500
Bleaching	1,500	750	500
Papermaking	2,000	1,000	500
Steam and Power	2,000	1,000	500
User-Customized	3,500	2,000	1,000
ASSOCIATE MEMBER COMPANY			
Chemical Pulping and Recovery	\$ 3,500	2,000	1,000
High Yield Pulping	2,500	1,500	1,000
Bleaching	2,500	1,500	1,000
Papermaking	3,500	2,000	1,000
Steam and Power	3,500	2,000	1,000
User-Customized	6,000	3,500	2,000
NON-MEMBER COMPANY			
Chemical Pulping and Recovery	\$ 5,500	3,000	1,500
High Yield Pulping	4,000	2,000	1,500
Bleaching	4,000	2,000	1,500
Papermaking	5,500	3,000	1,500
Steam and Power	5,500	3,000	1,500
User-Customized	9,500	6,000	3,000

DOE Proposal

The Process Modeling and Simulation Group has submitted a very detailed proposal to the Department of Energy. Entitled, "Optimizing Fiber Processing in the Pulp and Paper Industry," the work includes two millwide simulations which will be optimized based on energy costs and product specifications (Appendix I). The simulations, probably of a linerboard and a newsprint operation, will give us the opportunity to "fine tune" the PAT modules which Gary Jones has developed and the publicity will undoubtedly attract additional users of MAPPS. A more detailed description of this proposal is presented in another section of this report.

The Project Leader for the proposal will be Gary Jones and he will be assisted by other members of the Group as required. As noted earlier, if the project is approved as presented, the human resources of the Group will have to be expanded by one or two full time appointments at the "technician" or "assistant engineer/scientist" level.

Student Paper Contest

The Institute is sponsoring a Student Paper Contest on "The Use of MAPPS for Pulp and Paper Applications" (See Appendix II). Students from any academic institution with access to MAPPS can enter the contest and the entries will be judged by a panel consisting of one representative from each of the institutions and one or more representatives from the Tappi Journal. The best paper will be published in the Journal and all papers recommended by the panel of judges will be considered for publication. The top three winners, if qualified, will be offered a full scholarship with stipend to the Institute and will also receive a small cash award. The deadline for submittal of papers will be December 31, 1989.

The contest will be publicized by direct mailings to all of the current academic users of MAPPS, by announcements in the Tappi Journal, and through the TAPPI Student Chapter Association. To assure that any student can enter the contest, we will be pleased to license MAPPS to all interested academic institutions per our current licensing agreement.

Publications

Efforts to encourage the presentation and publication of MAPPS-related papers and articles by our users will be intensified. For unknown reasons, our competitors have, in the past, been more successful in soliciting stand-alone or co-authored papers. However, the unique PAT features of MAPPS and the DOE project should present us with a number of opportunities to solicit papers.

Currently, we are hopeful that Xuan Nguyen of Champion International will co-author Gary Jones' paper on PAT modeling to be presented at the 1989 TAPPI Engineering Conference. Xuan has already been very cooperative in obtaining data and samples from a Champion newsprint mill. To provide an even more complete range of data and samples, from the woodyard through the paper mill, we have also requested permission to visit this mill with Xuan and collect and/or co-ordinate the collection of additional samples and operating data. IPC would then perform the required testing and modify the current models to fit the new quality and operating data.

New Brochure

A new, expanded MAPPS brochure emphasizing the beneficial spinoffs from the academic, research, and communications efforts of the Institute is being designed and a "rough draft" should be available at the PAC meeting. The unique and powerful features of MAPPS, i.e., the detailed process models, PAT's, optimization, and the interactive interface, will be touted. The pricing structure for

both source code and compiled micro options will be listed and an easy-to-use tear-out for the reader to send for additional information will be included. Two versions of the brochure, one suitable for mass mailings and a slicker version designed for one-on-one marketing, are being considered.

New Releases of MAPPS

The timing for distribution of the new brochures must be coordinated with a new release of MAPPS. The early plan, now delayed due to the loss of personnel, was to release a new version which would include both PAT's and the new executive/interactive interface in the fourth quarter of 1989. The fall-back plan now is to release a PAT's version of MAPPS to coincide with Gary Jone's paper for the 1989 TAPPI Engineering Conference in September. Although this version will not have the new executive, a stand-alone interactive interface can be included to ease the demand by users for a friendlier interface.

Mary Berceau is continuing to work on the requirements/ specifications phases of the development of a new executive/ interactive interface on a contract basis. However, the number of hours she has available to work has been drastically reduced and it is unlikely that the actual coding can begin before the move to Atlanta. Our current estimate is that a new executive release will not be ready before the first quarter of 1990.

CEC Courses

Two MAPPS courses have been scheduled by the CEC for September, 1989, the week following the TAPPI Engineering Conference. "Introduction to Process Simulation with MAPPS" will be offered on September 18-19, followed by "MAPPS for the Advanced User" on September 20-21. Both of these courses will stress the new features of MAPPS, particularly PAT's. The advanced course will also address optimization techniques with MAPPS.

Consulting Services

The Group has always offered its services to the member and associate member companies of the Institute and, in a few instances to other companies on a fee basis. However, we have not aggressively marketed services such as setting up and/or maintaining simulation models of pulp and paper operations. We could also offer to conduct private generic seminars covering the techniques of process analysis and modeling and MAPPS seminars on specific process systems or product quality modeling, in addition to our regular Training Courses and CEC Courses.

Target markets, in addition to pulp and paper companies, could be small engineering firms or individual consultants and suppliers of process or process control systems. During 1989, we will make contact with potential clients by mass mailings and possibly by some discrete trade journal advertising campaigns.

Trade Shows

The Group plans to rent booths to demonstrate MAPPS at the 1989 Tappi Engineering Conference in September, 1989 and at the 1990 TAPPI Annual Meeting and Exposition in the spring of 1990, both scheduled to be held in Atlanta. We will showcase PAT Modeling at the fall show and the spring show, we will be able to introduce the new executive/interface version of MAPPS.

Five-Year Plan

A new five-year plan is being developed for the Process Modeling and Simulation Group. The plan will recommend that the name of the group be formally changed to "Systems Analysis Group" so that other forms of simulation (fluid mechanics, discrete event, etc) and such subjects as process control, AI/expert systems, and structured analysis and CASE (Computer Aided Software Engineering) tools can be investigated.

A major recommendation of the plan will be that a dynamic simulation version of MAPPS, to include the modeling of process control hardware and software elements, as well as process and PAT models and time constraints, be developed and licensed as a separate package. Although simpler dynamic capabilities could be incorporated into the current steady state version of MAPPS, the dynamic features would likely complicate the option of offering compiled micro versions. Positively, however, the development of a dynamic simulator, capable of modeling, in real time, process and process control variables and product quality attributes would greatly expand the horizons of the Systems Analysis Group.

A suggested name for such a simulator, which would likely require the inclusion of expert systems and structured analysis techniques, is ADAPPS (Automated Dynamic Analysis of Pulp and Paper Systems).

MAPPS SUPPORT

Since the last reporting period, MAPPS support requirements have been minimal. MAPPS users have either had no problems or have been able to solve them internally. Our electronic bulletin board, MAPPS-TALK, has also been largely ignored by users.

On a recent visit to the Georgia Tech Campus, we found that Georgia Tech, one of our heaviest academic users, was using a 2.0 version of MAPPS. We have now upgraded this user to Version 3.2 (NOTE: Version 3.0 and 3.1 are functionally identical to 3.2; these versions were noted internally because of changes in the Microsoft compilers we use.). If there are other qualified users having versions older than 3.0 who would like to upgrade, please contact Jim Rushton (414/738-3293) or Mike Schreiter (414/738-3305).

User Issues

At the time of this writing, we are attempting to move the MAPPS-TALK bulletin board service to an IBM PS/2 model 80 computer running the SCO Xenix operating system. This computer is owned by the IPC library staff and has a communication management software program that will make an excellent bulletin board system. This program can be used by any IPC group to set up their own communications/mail/bulletin board service for clients. We will be the first to take advantage of this capability.

The program is entered via the Xenix operating system. Users of the new MAPPS-TALK will first need to log in as a Xenix user and then log in as a bulletin board user. We will establish a special Xenix login for all MAPPS-TALK users that will take them directly to the new MAPPS-TALK. There is a special communications program for use on IBM PC's and compatibles for calling the bulletin board system. This communications program and a complete user's guide will be issued to all MAPPS users in the near future.

We hope to maintain the same MAPPS-TALK phone number on the new system.

Training Courses

No formal MAPPS training courses have been scheduled since the last reporting period. However, one academic user, Bob Rouda of the University of Minnesota, did come to Appleton for an informal training session. Nancy Sell, from the University of Wisconsin-Green Bay is also expected to set up an informal training session in the near future.

Maintenance Issues

We have successfully ported the entire MAPPS program to our new Unix minicomputer and will be using the Unix version as our official support version. This means that all source code maintenance will occur on the Unix computer. Source code for PC-MAPPS will be derived from the Unix source code. This has several important implications for the end user of MAPPS:

- 1) We now have the capability of full MAPPS program source-level debugging.
- 2) Source code maintenance is systematized under the Unix "Source Code Control System", meaning that all subroutines and data files will be given version numbers. Updates to individual subroutines can occur without the need for issuing complete new release versions.
- 3) MAPPS is now available on 1/4 inch tape cartridges (DC 600 XTD - high density 150 MByte capacity only) in either Unix or DOS formatted files.
- 4) We would like to discontinue support for 9-track tape versions of MAPPS.

IMPORTANT NOTE TO USERS GROUP: Unless user input to this strategy is negative, we will no longer support the 9-track tape versions after December 31, 1989.

- 5) A Unix version of MAPPS can be made available on either double or high density 5 1/4 inch floppy disks.

CONTINUING DEVELOPMENT OF MAPPS

The major development projects to enhance MAPPS continue to be PAT Modeling and the new executive/interactive interface. These and other developments which may be of interest to the reader are discussed below.

PAT Modeling

Gary Jones' continuing work on PAT's has included both the enhancement of existing models and the development of new models. A rough draft of a portion of the documentation for this work is available at this meeting for interested readers. As noted above, we anticipate releasing a PAT's version of MAPPS, coincidental with the presentation of Gary's paper at the TAPPI Engineering Conference, in September, 1989.

Beta Test Package

The beta test version of MAPPS incorporating new performance attributes and process modules is ready for testing by the user community. The test package includes source and executable code, data files and preliminary documentation. In addition to the usual MAPPS data files (module, stream and PAT data bases), the package includes data files for a new kraft mill, a stone groundwood mill and a papermachine simulation.

To date, Georgia Tech is the only user who has expressed interest in the beta test package. If other users are interested in working with the PAT version, please contact Jim Rushton (414/738-3293) or Gary Jones (414/738-3230).

New Module

The new modules are set up to be easily used. Input data requirements are minimal. Most required data are meaningful and commonly known design features and operating conditions. All model parameters are set by default but can be overridden.

The following modules should make it possible to simulate both chemical and high yield pulping, bleaching and papermaking. Recovery and steam and power modules are omitted. The new modules are designed to make it easier to initialize and convert streams and to set up meaningful simulations.

The new modules included in the test package are as follows:

Calender
Sheet forming

CALEND
FOUR01

PAT modifier	GENPRS
PAT initialization	PAPSIM
Properties	PROPS
Separator	SEPAR3
Wood block	WOOD02
Wet Press	WPRESS

Sheet Forming

The sheet forming model, FOUR01, includes a headbox, gravity drainage section, foils, table rolls, wet and dry vacuum box sections and a dandy roll. The module can be set up to simulate a single element, a group of elements or the entire machine. Output includes profiles of drainage rate, white water consistency and mat basis weight. The module simulates mat consolidation, formation effects, orientation and stretch, and two-sidedness. Retention, white water consistency, mat consistency, drainage rates and other characteristics can be controlled by the user.

Wet Pressing

The wet press module, WPRESS, simulates a single nip wet pressing operation. The rate of water removal from the web is based on a dynamic compressibility model and the web network is consolidated based on web compressibility. The wet press influences the final sheet density and strength, as well as Z-D structure and sheet two-sidedness.

Calendering

The calender module, CALEND, simulates the main effects of a single nip of a multiple-nip calender stack. Sheet bulk reduction is modelled through the nip intensity factor which is a function of calendering speed, nip load, roll radius and paper moisture and temperature. Heat transfer in the nip and on the roll surface, and moisture added to the sheet will influence property development on each side of the sheet. Both handsheet and machine-paper properties are calculated.

Species Data Base and Wood Block

The wood pile modelled by WOOD02 is a significant advancement over the earlier module, WOOD01. Both paper and pulping streams can be initialized. Component flows may be initialized for either stream type by simply specifying the species. Most performance attributes are computed by default.

Attribute Modifier

GENPRS is a module which is designed simply to change one or more PAT's by an arbitrary amount. All other PAT's and material streams pass through unchanged. This module is designed for case studies, to adjust PAT's to measured values or to simulate a general process which has some intended effect on PATs but does not influence mass or energy flows.

Sheet Properties

The PROPS module computes handsheet and machine-made paper properties for a material stream. The user can control the wet pressing pressure, fiber orientation, stretch and formation of the handsheet. Machine paper properties are based on the actual PAT values in the stream.

Modified Modules

The following modules have been modified to compute new attributes or to modify attributes. With the exception of HYRFN1 and CONVRT the input data is unchanged from MAPPS 3.0.

Alkaline extraction	ALKOXY
Generic bleaching	BLCH01
Chlorine dioxide bleaching	CLDIOX
Chlorination	CHLORN
Clarifier	CLAR01
Consistency	CONSIS
Stream conversion	CONVRT
Kraft digester	DIGR01
Dryer	DRYER1
Screening, cleaning and thickening	HYFRAC
Refiners	REFNR1 and HYRFN1
Disk saveall	SAVALL
Screening	SCRNO1
Separator	SEPAR1
Stream mixer	STOMIX
Stream splitting	SPLIT1

In addition to the modules shown above, all other modules in the MAPPS library will run with these new modules with the exception of the mixer block, MIXR01. STOMIX should be used to perform all stream mixing involving PATs. STOMIX can be used even if attributes are not used.

Stream conversion is also made easier through the modified version

of the CONVRT block. The modified CONVRT now allows for conversion between pulping, bleaching and paper stream types without any additional information other than the new stream type. Conversions are performed using PAT variable information. Stream conversions can be made in the usual way.

General Purpose Modules

The general purpose modules listed below are included in the beta test package. None of these modules has been changed. They are already set up to handle PAT's by default. Conspicuous by their absence are modules for simulation of black liquor recovery or steam and power production. Since performance attributes are not applicable in these process areas, they were not included.

Switch	SWITCH
Heat exchanger	HEXCH1
Flash	FLSH01
Stream convergence	CONVRG
Black liquor control	BLIQ01
White liquor control	WLIQ01
Washers	WASH01, WASH02
Controller	PCONT1
Pump	PUMP01
Controller splitter	CONSPL

Utility Modules

There are a large number of new utility modules. For details please refer to the documentation.

Dimensions

In order to accommodate the large number of modules into 640K, the executable module has been dimensioned to handle up to 100 streams and modules. To avoid unexpected results, flowsheets modeled with this version of MAPPS should not contain more than 100 modules or streams. To change the dimensioning constraints, you should consult the programmers guide and determine how to redimension the appropriate arrays. After redimensioning, it will be necessary to recompile and relink. If the array dimensions are increased significantly, you will probably have to reduce the number of modules included in the relinking step.

New Data Files

The beta test comes with data files for a kraft mill, stone ground-wood mill and paper machine simulation.

The kraft mill simulation includes screening, refining and saveall systems, a bleaching system and a final refining step. The bleaching system consists of chlorination, extraction, washing and hypochlorite bleaching stages. The new wood block, stream conversion block, modified digester, the detailed screening, cleaning and refining blocks (HYFRAC and HYRFN1), and the property block (PROP) are all included in the kraft flowsheet.

The papermachine simulation includes a Fourdrinier model, wet press models, modified dryers, property blocks and a saveall. The Fourdrinier module, set up to simulate the entire wire in one block, includes the headbox, gravity forming section, foil section, wet vacuum and dry vacuum box sections.

The stone groundwood simulation is similar to the TMP flowsheet supplied with the current version of MAPPS but the new stream conversion block and modified bleaching modules have been added.

The new version of MAPPS will also run the simulation data files included in the current version of MAPPS, i. e., the kraft pulpmill PULPMILL.DAT, paper machine, PAPER.DAT, bleach plant, BLEACH.DAT, and steam and power plant, POWER.DAT. However, unless the user redimensions the arrays as noted above, the streams and modules must be re-numbered so that neither exceeds the maximum number of 100.

Documentation

Documentation will be provided in the form of three manuals.

- 1) An overview of the PAT system of models describing the new features and the theoretical concepts.
- 2) Module documentation in the standard worksheet format.
- 3) Technical documentation (models).

Before attempting to use the PAT version, it is recommended that the user read the overview manual in order to understand interactions between attributes, and process conditions etc.

Applications

Two new applications have been developed using one or more of the above flowsheets. The first application shows the effect of multiple repulping on sheet properties. The predicted results are compared to data from McKee and Bobalek et. al. In this application, the kraft pulp production is simulated over a range of freeness levels and handsheets are simulated at two pressing levels. Good agreement was obtained for cases using pulps of three species, 100 % southern softwood, 100 % northern softwood, 100 % northern hardwood, and a mixture of these species.

In all cases, the fibers become stiffer with each drying step; analogous to an increase in cell wall thickness of 50% over six repulpings. As the fibers become stiffer, debonding occurred at lower freeness levels and higher wet pressing pressures than those used by McKee. In terms of end-use product quality, the sheet density and tensile properties decreased while tear and scattering coefficient increased.

The results are quite different using data for repulped sheets made by Bobalek et. al at higher freeness levels and zero pressure. For these sheets, sheet density and zero-span tensile both increased with repulping, indicating that bonding and fiber development continue with each repulping. However, both MD and ZD tensile strength decreased, an effect that the authors attribute to debonding.

With the exception of the drop in MD tensile, the predicted simulation results agree with the data of both Bobalek and McKee. However, the observed drop in breaking length observed by Bobalek can be predicted if formation efficiency is decreased with repulping under these low densification conditions. This assumption of decreased formation efficiency is entirely plausible for sheets made at high freeness and zero pressing pressure.

The second application is a simulation of newsprint mill which includes a kraft mill, bleached stone groundwood mill and paper machine. The application serves two purposes, as a comprehensive test of the new modules and as a partial validation against mill data. Operating and property data have been provided by Xuan Nguyen of Champion International. This application is discussed further under STUDENT WORK and MEETINGS and PAPERS.

Executive/Interactive Interface

Mary Berceau and Mike Schreiter have been applying structured program design techniques in developing the new MAPPS executive/interactive editor and command interpreter. Most programming texts refer to a "Software Product Development Life Cycle" which consists of the following steps:

- 1) Requirements Analysis and Definition
Define the project and the required product.
- 2) Program Specification
Identify the detailed functions of the proposed software product.
- 3) Program Design
Identify the programming concepts to be used (top-down, bottom-up, CASE tools, etc.), create logic flowcharts, data diagrams, etc.
- 4) Program Development
Write the program.
- 5) Verification and Testing
Check the function of the program against the design and specifications. Check for programming errors.
- 6) Performance Appraisal
Check that the program operates efficiently in the intended environment(s).
- 7) Operation and Maintenance
On-going program maintenance.
- 8) Configuration Management
Incorporate changes into the program.

We are currently in the Specification and Design stages of development. These steps require end-user input to specify the required functions of the new interface. We have been accumulating input over the past few years and have compiled a preliminary list of program "requirements", "goals" and "preferences". This list will be circulated for user comment.

Actual design of the program will not begin until we have decided upon a firm set of program specifications. Programming will not begin until the design is determined. We anticipate completion of the specification and design stages by mid-summer (1989).

Revision of Documentation

We have received many comments over the years suggesting improvements to our existing MAPPS documentation. Mary Berceau and Mike Schreiter have been working to define (or re-define) the MAPPS program documentation needs based on these comments. The following set of documents is being proposed:

- 1) MAPPS Tutorial
Step-by-step example of using MAPPS for the novice user.
- 2) PC-Installation Manual
Procedures for installing and modifying MAPPS on the PC under DOS using the Microsoft Fortran Compiler.
- 3) MAPPS User's Guide
Introduction to process simulation and MAPPS.
MAPPS program organization and command structure.
- 4) MAPPS User's Reference Manual
Summary of MAPPS commands and procedures.
- 5) MAPPS Module User's Guide
Module summaries and parameter worksheets.
- 6) MAPPS Module Technical Reference Manual
Technical description of mathematical model.
- 7) MAPPS Programmer's Guide
Programming procedures and techniques.
- 8) MAPPS Programmer's Reference Manual
Executive and utility subroutines, common variables, data structures.

The development of the new editor/executive will require complete re-writes of the User Guide, User Reference, Programmer Guide, and Programmer Reference. These re-writes will accommodate corrections necessary for the new PAT system as well.

The Installation Guide, User Reference and Tutorial will be new documents. The Installation Guide is partially complete and is being sent with all new PC MAPPS purchases.

The Module Guide and Reference Manual will be updated as time permits. All new module documentation will be released in the new format. We are currently working on defining the new format.

Optimization

Since the last report period, no further development of the interface for the OPT and OPTLIB optimization programs (Design Productivity Center, University of Missouri-Columbia) has occurred. However, the DPC has indicated its willingness to cooperate in a joint marketing plan whereby they would provide the license for OPT and OPTLIB and the Institute would provide the license for a MAPPS version containing the interface. To date, we have supplied the interface to one MAPPS User-company.

S. D. Warren Interface

A number of users expressed an interest in the S. D. Warren interface program for MAPPS demonstrated at the Fall, 1988 User's Group Meeting. IPC has contacted Mr. David Kreiton, Manager of Process Control/Engineering at S. D. Warren and proposed that Warren sell the code to IPC. Mr. Kreiton indicated that they would possibly be willing to sell the code with its available documentation, as is, with no support, but that S. D. Warren would retain a copy of the code and the right to use it. To date, however, Warren has not officially confirmed this decision nor have they established a price for package.

NEW DEVELOPMENT ISSUES

With the completion of PAT Modeling and the new executive/interface, further developments of the steady state version of MAPPS will likely be limited to activities such as improving the code, writing new process modules or revising existing modules and, possibly, the addition of expert system capabilities to assist users in analyzing and modeling their processes. These developments are needed and will be included in the future activities of the Group. However, to enhance the products and services the Institute can provide to Member and Associate Member Companies and to assure the continued technical and economic viability of the Process Modeling and Simulation Group (hopefully, the Systems Analysis Group soon), new developments should be considered.

ADAPPS, a New Dynamic Simulator

As noted above, a new dynamic simulator could be developed, using many of the same process and PAT modules, but with added modules to simulate process and process control dynamics. Expert systems could be included to assist a user with limited process or process control knowledge in setting up his model. It would also be desirable to have the capability to include the hardware and software required for process control so that sophisticated control systems such as those for MD and CD profiling control (paper machines) or pulp or paper production control could be modeled. The "Structured Analysis" technique for analysis of process and process control procedures and provisions for the inclusion of Computer-Aided Software Engineering might also be appropriate for this simulation package.

Any meaningful effort in the development of ADAPPS will require additional staffing and, most probably, additional hardware and software. To fund this effort, we plan to determine whether a joint project with one or more DCS vendors can be organized and managed by the Group. We are hopeful that participating vendor companies will contribute to both staffing and hardware/software requirements.

Expert Systems Applications

The Group already has some limited experience with the use of expert system shells for process analysis. The development of packaged expert systems for process analysis and troubleshooting, using these shells or written from scratch using the LISP or PROLOG language, is a natural way to further couple the capabilities of this Group with other "experts" at the Institute and in the industry. Industry participation and funding of this effort will also be investigated.

Other Simulation Techniques

Gary Jones has been working with students and other faculty members on such specialized simulations as the dynamic modeling of fluid flow in a headbox. In 1988, Paper Production Scheduling and Product Tracking systems were the most widely installed "millwide" systems in the industry (Fadum Report, December, 1988). Discrete simulation models, using expert systems, could be used to predict the behavior of these systems. The investigation of specialized simulation procedures, as illustrated by these two examples, could result in the development of additional products or consulting services of interest to the industry.

DOE PROPOSAL

A proposal for funding of performance attribute modelling work has been submitted to the Department of Energy. The proposal, titled "Optimizing Fiber Processing in the Pulp and Paper Industry", has the following components: two large mill case studies, laboratory studies, process control applications and model development and expert systems. The proposal requests \$865 K over a four year period beginning in 1990.

The centerpiece of the proposed project will be two mill case studies. These will involve detailed simulation of two mills producing representative grades which are sufficiently different to validate different aspects of the Performance Attribute Models. The two targeted grades are newsprint and linerboard. The case studies will serve several purposes: detailed validation of the models, targeting of areas for improvement in the models, and establishing credibility with the potential user community and user requirements.

The case studies will provide detailed analysis of the mechanisms of property development for the existing operation and means of improving or maintaining performance with reduced energy consumption through the use of optimization techniques.

Although the primary activities will involve computer applications, some laboratory work will be needed to generate basic information to improve existing PAT models or to add new PAT models. Some experiments may be used to validate some key assumptions of the model.

After a significant portion of the mill cases have been completed, work should begin on the integration of this system into process control and mill information systems in one or more of the case study mills.

Although the bulk of the PAT system is now in place, the modelling development will continue, particularly some additional aspects of papermaking which will be studied and incorporated into the model. In its later stages, the modelling effort may also include the development of one or more expert systems to handle the effects of equipment details not easily included in deterministic models.

The second and perhaps more important portion of the modelling task is the addition of an expert front-end (user-friendly interface) to aid the user in constructing a process model and to provide advice on the use of performance attributes.

STUDENT WORK AND IPC COURSES

The newsprint mill application has been developed in part by Paul Rosik as his A190 Master's Degree project. The A190 report will summarize all experimental results, compare experimental and simulation predictions and show the effects of varying the stone groundwood to kraft pulp ratio on handsheet and machine paper properties and machine runnability.

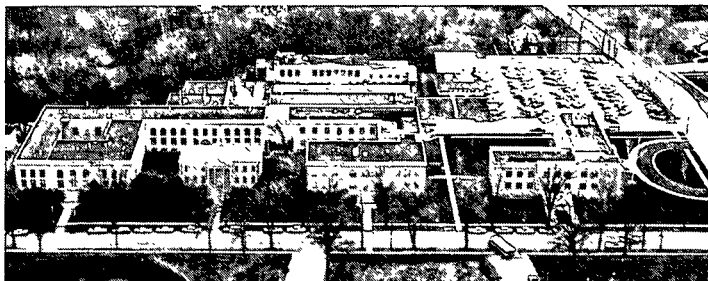
A second A190 project by Roger Tembruell is the simulation of a six tube experimental manifold using FLUENT, a finite difference computer program. The manifold was modelled in three dimensions using approximately 10000 nodes and pressure boundaries.

The original objective was to simulate experimental conditions on a physical model built by Beloit Corp to investigate turbulence generation and flow distributions using LDA techniques. Unfortunately, due to difficulties with the apparatus, the experimental data were not available for the A190 project. However, simulations were made of a number of different outlet pressure conditions many of which were in general agreement with observations of Mardon and others.

The simulations provided detailed pictures of the distributions of velocity, pressure and turbulence kinetic energy along the manifold and along each tube. The key development was the understanding of the sensitivity of the flow asymmetry along the tube bank to the pressure balance across the manifold.

Portions of this work will be presented at the TAPPI Engineering Conference in the sessions sponsored by the Committee on Fluid Mechanics. By the time of presentation, the paper will contain some experimental data for comparison with the simulation results.

Two new courses are being considered for the 1989-1990 academic year to kick off the new season at Georgia Tech. These courses, the first in modelling techniques and simulation fundamentals and the second stressing applications mainly with MAPPS, are designed to develop a better understanding and appreciation for the power of simulation. Your comments and suggestions about the content and features of these courses would be appreciated.



THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

SYSTEMS ANALYSIS PROJECT ADVISORY COMMITTEE

and

MAPPS USERS GROUP

SLIDE MATERIAL

March 28-29, 1989

PERSONNEL

PERSONNEL LOSSES

MARY BERCEAU - ASSISTANT ENGINEER

MIKE SCHREITER - ASSISTANT SCIENTIST

NEW PERSONNEL

REX SKIFSTAD - MICRO COMPUTER SUPPORT TECHNICIAN

ERIC PODOLSKI - TECHNICIAN III (PART TIME)

MARY BERCEAU - ASSISTANT ENGINEER (PART TIME - OFF SITE)

NEW USERS

COMMERCIAL USERS

MACMILLAN BLOEDEL INC.

ACADEMIC USERS

UNIVERSITE DU QUEBEC A TROIS-RIVIERES

TUSKEGEE UNIVERSITY

UNIVERSITY OF WISCONSIN - GREEN BAY

UNIVERSITY OF MINNESOTA

MEETINGS AND PAPERS

PAPERS BY GARY JONES

"NEW DIRECTIONS IN PROCESS SIMULATION"

PIMA/MIS INTERNATIONAL CONFERENCE

APRIL 19-21, 1989

CINCINNATI, OHIO

"STRATEGIES FOR END-USE PERFORMANCE"

TAPPI CONTAMINANT PROBLEMS AND STRATEGIES

IN WASTE PAPER RECYCLING SEMINAR

APRIL 24-26, 1989

MADISON, WISCONSIN

MEETINGS AND PAPERS

PAPERS BY GARY JONES

"ANALYSIS AND SIMULATION OF PROPERTY DEVELOPMENT IN FORMING
NEWSPRINT" AND "ANALYSIS OF FLOW AND TURBULENCE GENERATION IN
AN EXPERIMENTAL MANIFOLD WITH THE AID OF A COMPUTATIONAL FLUID
MECHANICS PROGRAM"

1989 TAPPI ENGINEERING CONFERENCE

SEPTEMBER, 1989

ATLANTA, GEORGIA

MEETINGS AND PAPERS

1989 PROCESS AND PRODUCT QUALITY DIVISION CONFERENCE

SESSION ON "PRODUCT QUALITY MODELING"

OCTOBER 1-6, 1989

NEW ORLEANS, LOUISIANA

BUSINESS PLANNING AND MARKETING ACTIVITIES

MICRO COMPUTER PRICING OPTIONS

	SINGLE COPY	SECOND COPY	ADD. COPIES (EACH)
MEMBER COMPANY			
CHEMICAL PULPING & RECOVERY	\$ 2,000	1,000	500
HIGH YIELD PULPING	1,500	750	500
BLEACHING	1,500	750	500
PAPERMAKING	2,000	1,000	500
STEAM AND POWER	2,000	1,000	500
USER-CUSTOMIZED	3,500	2,000	1,000
ASSOCIATE MEMBER COMPANY			
CHEMICAL PULPING & RECOVERY	\$ 3,500	2,000	1,000
HIGH YIELD PULPING	2,500	1,500	1,000
BLEACHING	2,500	1,500	1,000
PAPERMAKING	3,500	2,000	1,000
STEAM AND POWER	3,500	2,000	1,000
USER-CUSTOMIZED	6,000	3,500	2,000
NON-MEMBER COMPANY			
CHEMICAL PULPING & RECOVERY	\$ 5,500	3,000	1,500
HIGH YIELD PULPING	4,000	2,000	1,500
BLEACHING	4,000	2,000	1,000
PAPERMAKING	5,500	3,000	1,500
STEAM AND POWER	5,500	3,000	1,500
USER-CUSTOMIZED	9,500	6,000	3,000

BUSINESS PLANNING AND MARKETING ACTIVITIES

DOE PROPOSAL

TITLE

"OPTIMIZING FIBER PROCESSING IN THE PULP AND PAPER INDUSTRY"

PURPOSE

**OPTIMIZE MILLS BASED ON ENERGY COSTS AND REQUIRED PRODUCT
SPECIFICATIONS**

BUSINESS PLANNING AND MARKETING ACTIVITIES

DOE PROPOSAL

SIMULATIONS

LINERBOARD AND NEWSPRINT MILLS

PROJECT LEADER

GARY JONES

PERSONNEL

WILL REQUIRE ADDITIONAL RESOURCES

BUSINESS PLANNING AND MARKETING ACTIVITIES

STUDENT PAPER CONTEST

SUBJECT

THE USE OF MAPPS FOR PULP AND PAPER APPLICATIONS

PUBLICITY

**MAY AND SEPTEMBER ISSUES OF TAPPI JOURNAL
TAPPI STUDENT CHAPTERS
MAPPS ACADEMIC USERS**

BUSINESS PLANNING AND MARKETING ACTIVITIES

STUDENT PAPER CONTEST

AWARDS

SCHOLARSHIP TO IPC IF QUALIFIED
FIRST PLACE WINNER PUBLISHED IN JOURNAL
ALL OTHERS REVIEWED FOR PUBLICATION
CASH AWARD TO FIRST THREE WINNERS

JUDGES

PANEL CONSISTING OF REPS FROM ACADEMIC INSTITUTIONS AND TAPPI
JOURNAL

BUSINESS PLANNING AND MARKETING ACTIVITIES

PUBLICATIONS

XUAN NGUYEN AND GARY TO CO-AUTHOR PAPER AT TAPPI ENGINEERING.
ARRANGEMENTS MADE FOR ADDITIONAL SAMPLING AND DATA COLLECTION TO
"FINE-TUNE" PAPER.

BUSINESS PLANNING AND MARKETING ACTIVITIES

NEW BROCIURE

EMPHASIZES BENEFICIAL SPINOFFS FROM ACADEMIC, RESEARCH AND
COMMUNICATIONS EFFORTS OF THE INSTITUTE

EMPHASIS ON UNIQUE AND POWERFUL FEATURES OF MAPPS, I. E.
PROCESS MODELS, PAT MODELING, OPTIMIZATION, NEW INTERFACE (UNDER
DEVELOPMENT).

NEW PRICING OPTIONS

DISTRIBUTION BY SELECTIVE MAILINGS AND "ONE-ON-ONE" INTERACTIONS

BUSINESS PLANNING AND MARKETING ACTIVITIES

NEW MAPPS RELEASES

PAT MODELING

TEST VERSION WITH DOCUMENTATION AVAILABLE IN APRIL

OFFICIAL "BETA" TEST IN EARLY FALL

COMMERCIAL RELEASE ASAP

NEW EXECUTIVE/INTERACTIVE INTERFACE

DEVELOPMENT UNDERWAY; COMPLETION DEPENDS ON
RESOURCES AVAILABLE

INTERIM INTERFACES

S. D. WARREN INTERFACE
MENU DRIVEN FRONT END FOR EXISTING EXEC.

BUSINESS PLANNING AND MARKETING ACTIVITIES

CEC COURSES

"INTRODUCTION TO PROCESS SIMULATION WITH MAPPS"

SEPTEMBER 18-19

"MAPPS FOR THE ADVANCED USER"

SEPTEMBER 20-21

BUSINESS PLANNING AND MARKETING ACTIVITIES CONSULTING SERVICES

SET UP AND MAINTAIN SIMULATION MODELS OF MILL OPERATIONS
CONDUCT SEMINARS ON TECHNIQUES FOR PROCESS ANALYSIS USING
SIMULATION MATERIAL AND ENERGY BALANCES
 PAT MODELING

TRADE SHOWS

1989 TAPPI ENGINEERING CONFERENCE AND EXHIBIT
SEPTEMBER, 1989
ATLANTA MARRIOTT

TAPPI 90
MARCH 5-8, 1990
GEORGIA WORLD CONGRESS CENTER

FIVE-YEAR PLAN

ISSUES TO CONSIDER CHANGE NAME TO "SYSTEMS ANALYSIS GROUP"
 DEVELOP DYNAMIC SIMULATOR
 EXPERT SYSTEMS FOR PROCESS ANALYSIS
 OTHER SIMULATION TECHNIQUES

PAPERS AND PUBLICATIONS

□ TAPPI CONTAMINANTS AND SECONDARY

FIBER STRATEGIES SEMINAR

APRIL 24-26 MADISON, WI

"STRATEGIES FOR END-USE PERFORMANCE"

□ PIMA/MIS INTERNATIONAL CONFERENCE

APRIL 19-21, CINCINNATI, OH

"NEW DIRECTIONS IN PROCESS SIMULATION"

□ TAPPI ENGINEERING CONFERENCE - ATLANTA

• TWO PAPERS

- PRODUCT QUALITY SIMULATION AND MODELLING SESSION

NEWSPRINT MILL SIMULATION RESULTS

- FLUID MECHANICS SESSION

MANIFOLD FLOW SIMULATION RESULTS

□ AIChE FALL MEETING - NOVEMBER - SAN FRANCISCO

CHAIRING SESSION ON SYSTEMS SIMULATION AND

OPTIMIZATION IN PULP AND PAPER

CO-SPONSORED JOINTLY BY TAPPI AND

AIChE FOREST PRODUCTS DIVISION

MAPPS PAT TEST

OBJECTIVES:

- TEST NEW VERSION OF MAPPS
WITH EXPANDED PERFORMANCE ATTRIBUTES
- OBTAIN USER FEEDBACK

PACKAGE:

- DOCUMENTATION
- EXECUTABLE MODULE, FORTRAN CODE
- SAMPLE DATA FILES (FLOWSHEETS)

NEW MAPPS MODULES

- SHEET FORMING FOUR01
- WET PRESSING WPRESS
- CALENDERING CALEND
- STREAM INITIALIZATION WOOD02
- PROPERTY CALCULATION PROPS
- PAT INITIALIZATION PAPSIM
- COMPONENT SEPARATION SEPAR3
- PAT MANIPULATION GENPRS

MODIFIED MODULES

ALL BLEACHING AND EXTRACTION MODULES

- ALKALINE EXTRACTION
- GENERIC BLEACHING
- CHLORINE DIOXIDE BLEACHING
- CHLORINATION
- HYDROGEN PEROXIDE BLEACHING
- OXYGEN BLEACHING

GENERIC

- CLARIFIER (CLAR01)
- CONSISTENCY (CON SIS)
- MIXING (STOMIX)

MODIFIED MODULES (CONT'D)

- STREAM CONVERSION (CONVRT)
- CHEMICAL PULPING (DIGR01)
- REFINING (REFNR1 AND HYRFN1)

STOCK PREPARATION

- SCREENING, CLEANING OR THICKENING

SCRN01 AND HYFRAC

- DRYING (DRIER1)
- SAVEALL (SAVALL)
- COMPONENT SEPARATION (SEPAR1)
- STREAM SPLITTING (SPLIT1)

NEW DATA FILES

- KRAFT MILL: PULPING, SCREENING, CLEANING
REFINING, TWO-STAGE BLEACHING, FINAL REFINING STAGE
STREAM CONVERSION, PROPERTY BLOCK
- STONE GROUNDWOOD MILL: STONE GRINDING, SCREENING,
CLEANING, CONSISTENCY CONTROL GENERIC BLEACHING, STREAM
CONVERSION

NEW DATA FILES

- NEWSPRINT PAPER MACHINE
 - STOCK MIXER MIXES SGW AND KRAFT
 - PAPER MACHINE - HEADBOX, GRAVITY DRAINAGE
FOILS, VACUUM BOXES
 - THREE WET PRESS NIP DEWATERING
 - WHITE WATER RECOVERY, SAVEALL
 - CAN DRIER SECTION
 - PROPERTY BLOCKS

DOCUMENTATION

- INTRODUCTION AND OVERVIEW OF PERFORMANCE ATTRIBUTES
- MODULE USERS GUIDE
- TECHNICAL DOCUMENTATION

DOE PROPOSAL

OPTIMIZING FIBER PROCESSING IN THE PULP AND PAPER INDUSTRY

OBJECTIVE: Develop and use quality models to improve the performance of products
produced in the domestic pulp and paper mills.

PROJECT PLAN

- TWO LARGE MILL CASE STUDIES
- LABORATORY STUDIES AND ANALYSIS
- MODEL DEVELOPMENT AND IMPROVEMENT
- EXPERT SYSTEMS IMPLEMENTATION
- PROCESS CONTROL APPLICATIONS

MILL CASE STUDIES

- NEWSPRINT AND LINERBOARD
- PROPERTY DEVELOPMENT ANALYSIS
- DETERMINE OPTIMAL PRODUCT PERFORMANCE
WITH REDUCED ENERGY CONSUMPTION
- INTEGRATE INTO PROCESS CONTROL SYSTEM
AND/OR MILL INFORMATION SYSTEM

EXPERT SYSTEMS

- USER-FRIENDLY INTERFACE
- INTERNAL KNOWLEDGE BASE TO HANDLE SPECIFIC EQUIPMENT
INFORMATION WHICH AFFECTS PROPERTY DEVELOPMENT

DEVELOPMENT ISSUES

CONTINUING DEVELOPMENT

PAT MODELING

GARY JONES

EXECUTIVE/INTERACTIVE INTERFACE

MIKE SHCREITER

REVISION OF DOCUMENTATION

MIKE SCHREITER

DEVELOPMENT ISSUES

CONTINUING DEVELOPMENT

NEW PROCESS MODELS

TWIN WIRE AND TOP WIRE FORMING

DUAL LAYER FORMING

COATING SYSTEMS

OPTIMIZATION

TENTATIVE JOINT MARKETING EFFORT WITH
DESIGN PRODUCTIVITY CENTER @ UNIVERSITY
OF MISSOURI-COLUMBIA

S. D. WARREN INTERFACE

CONTINUING TO INVESTIGATE

DEVELOPMENT ISSUES

NEW DEVELOPMENT ISSUES

ADAPPS

AUTOMATED DYNAMIC ANALYSIS OF PULP AND PAPER SYSTEMS

**PROPOSED JOINT DEVELOPMENT PROGRAM WITH PROCESS CONTROL
SUPPLIERS AND POTENTIAL INDUSTRY USERS**

**PROCESS AND PROCESS CONTROL DYNAMICS; MIGHT INVOLVE EXPERT
SYSTEMS, STRUCTURED ANALYSIS, CASE TOOLS, ETC.**

SIMILAR IN FUNCTIONAL ASPECTS TO "TRAINER"

CAPABLE OF RUNNING IN DCS ENVIRONMENT

DEVELOPMENT ISSUES

NEW DEVELOPMENT ISSUES

EXPERT SYSTEMS FOR PROCESS ANALYSIS

**USE EXPERT SYSTEM "SHELLS" OR PROGRAM FROM SCRATCH USING
LISP, PROLOG, ETC.**

**USE IPC AND INDUSTRY EXPERTS TO DEVELOP ANALYSIS AND
TROUBLESHOOTING GUIDES FOR ENGINEERS, MANAGERS, OPERATORS**

OTHER SIMULATION TECHNIQUES

COMPUTATIONAL FLUID MECHANICS

DISCRETE EVENT SIMULATION

ECONOMIC MODELING

STUDENT WORK

PAUL ROSIK A190 - MASTERS

PROPERTY DEVELOPMENT IN A NEWSPRINT MILL

OBJECTIVES:

- VALIDATE MODELS,
- UNDERSTAND INFLUENCES ON PROPERTY DEVELOPMENT
- PREDICT EFFECTS OF HIGHER SGW LEVELS

CHAMPION MILL

- KRAFT, SGW MILL AND #1 PAPER MACHINE
- PROCESSING CONDITIONS, HANDSHEET AND MACHINE PAPER

STUDENT WORK

ROGER TEMBREULL A190 - MASTERS

FLUID FLOW IN AN EXPERIMENTAL MANIFOLD

OBJECTIVES:

- SIMULATE AND UNDERSTAND THE DETAILED
FLUID FLOW AND TURBULENCE USING FLUENT
- DETERMINE EFFECTS OF PRESSURE BALANCE ON
VELOCITY PROFILES, PRESSURE CONTOURS,
TURBULENCE INTENSITY AND EDDY SIZE

Appendix I

Unsolicited Proposal

on

OPTIMIZING FIBER PROCESSING IN THE PULP & PAPER INDUSTRY

Proposal No. 3024

Submitted to

Office of Industrial Programs
Conservation and Renewable Energy
Department of Energy
Washington, D.C. 20585

January 26, 1989

Unsolicited Proposal
on
OPTIMIZING FIBER PROCESSING IN THE PULP & PAPER INDUSTRY

Prepared by
Engineering Division
The Institute of Paper Chemistry
Appleton, WI 54912

Submitted to
Office of Industrial Programs
Conservation and Renewable Energy
Department of Energy
Washington, D.C. 20585

Proposal No. 3024

January 26, 1989

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TITLE OF PROPOSAL: Optimizing Fiber Processing in the Pulp & Paper Industry

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KEY WORDS: end-use performance, quality, performance attributes, process control, process simulation, process modeling, expert systems, user-friendly interface

1. PROJECT SUMMARY

1.1 TECHNICAL SUMMARY:

The Institute of Paper Chemistry proposes to extend the Performance Attribute modeling capability of the MAPPS process simulation program to enhance the use of this model to optimize fiber process in pulp and paper applications, and thereby reduce energy consumption in the manufacturing process. A four-year program is proposed to complete the development of the Performance Attribute modelling capability, and to perform in-mill validation studies that will demonstrate the effectiveness of the model.

In recent years, the Institute has been exploring modification of its MAPPS process simulation package to include non-conservative parameters related to the papermaking potential of the fibers and the influence of processing on such attributes. MAPPS is a process simulation program developed by the Institute specifically to describe the mass and energy balances of traditional processing stages in pulp and paper manufacture. Performance Attribute modelling is a novel extension of this program with the potential to revolutionize decision-making in pulp and paper manufacturing. PAT modelling links the processing stages applied to well-characterized raw materials to predict the resulting attributes of paper products required for use in a variety of products.

The ability to balance raw materials selection and processing steps to produce a paper with a given end-use capability offers a host of opportunities for optimization of the paper manufacturing process, including significant

opportunities for reduced energy consumption in an energy-intensive industry.

Some of the potential benefits with energy implications include:

- reduced energy consumption through increased use of recycled and high yield furnishes
- reduced energy consumption through reduced fiber loss in manufacturing
- reduced energy consumption by eliminating off-specification product and subsequent recycle
- improved decision-making in process selection and capital equipment selection

The PAT capability of MAPPS will allow more rational selection of raw materials and subsequent processing steps to minimize the energy consumption. For example, many paper products use a mixture of chemical pulps (with high energy requirements in processing) and other pulps such as recycled fibers and high yield fiber (with much lower energy requirements). The mixture of chemical and other pulps is based on trial and error method for achieving the desired end-use properties such as strength and brightness. A 7% reduction in the amount of chemical pulp in newsprint, through a careful balance of raw materials selection and processing selection, may reduce energy consumption by as much as 1.4×10^{12} Btu/year.

To realize the potential of PAT modelling in MAPPS, the Institute proposes to:

- complete the development of Performance Attribute Modeling.
- perform in-mill trials to establish the validity of the models and make adjustments as necessary.
- develop a user-friendly interface to encourage the use of the approach.

It is estimated that this effort will require a four year effort at a total cost of \$1,525K, with \$865K requested from the Department of Energy.

2. SIGNIFICANCE OF THE PROBLEM

2.1 Industry Energy Usage

Energy Usage throughout the pulp and paper industry is shown in Table I. Approximately 50% of the energy requirements of the industry were generated internally (2).

Table I
USPI Specific Energy Consumption per ton (1975) (6)

<u>Paper Grade</u>	<u>Electrical(7)</u>	<u>Steam Rate lb/ton(8)</u>
Folding Box Board	375	NA
Linerboard (medium)	325	17,000-26,000
Newsprint	300	8,000-12,000
Writing Paper	350	8,000-14,000
Integrated Fine Paper	NA	18,000-30,000
Pulp Mill	NA	15,000-22,000

The breakdown of specific energy consumption for various pulping and paper-making processes (9) is shown in Table II.

Table II

<u>Process</u>	<u>Specific Energy Consumption</u> <u>10**3 BTU/ton</u>	<u>Kwh/ton</u>
Chipping	150-185	44-54
Kraft Pulping (+recov)	11,000	3,300
NSSC Pulping	6,400	1,900
Groundwood Pulping	3,100-4,200	910-1,230
Kraft Bleaching	4,106	1,200
Groundwood Bleaching	24	7.0
Refining	610-920	180-270
Sheet Consolidation & Drying	5,100-11,000	1,500-3,200

Consumption of purchased fuel in the US (USPI) (1973) (10) was equivalent to 1.2×10^{12} BTU's. This represented 45% of overall energy requirements. The remainder was generated internally from hogged fuel such as bark, slabs, and scraps. According to API, between 1972 and 1981, the industry used 23.3% less purchased energy, while at the same time, productivity had increased by almost 20%.

The amount of energy needed to produce a ton of paper from wood averages about 30 MM Btu (11). Projected total energy demand for the industry for 1990 is $2,620 \times 10^{12}$ Btu. Roughly 47% or 1,230 trillion Btu will be purchased energy.

2.2 The Impact of Process Control

Computerized process control could enhance throughput and quality of paper products with potential savings to the industry (11 and Office of Technology Assessment). Effective application of computer technology to energy management in mills has a potential of saving 10% of the total industry energy consumption with very low risk (11). A study found that quality specifications are judged higher and more consumptive of energy than necessary (11 p. 60.) and concluded that "the energy impact of reduced specifications needs to be studied; recommendations should be made as to acceptable levels of reduced specifications."

Introduction of improved process controls on the paper machine will either increase output by increasing machine speed, or reduce waste by increasing product uniformity. In either case, a reduction in energy use inevitably occurs when a process control system is installed. By reducing waste, the energy input per ton of saleable output would also be reduced (11 p. 77).

Studies have shown that millwide control can increase retained sales dollars by 4.1% through reductions in direct costs in raw materials, energy, overhead, and labor. The potential savings per mill was in the neighborhood of \$.5 to 2.8 million in 1984. These represent increased production of 2-5%, reduced raw material usage of 5% and improved energy efficiency of 1-2% (1).

Among the control systems currently in common use which impact product quality are the following: basis weight and moisture, thermal slice lip, caliper profile, and refiner power. Where installed, these systems have a total savings potential of \$3 million/mill/year (1).

Current obstacles to achieving quality targets include:

1. Paper quality targets are influenced by variable wood quality.
2. Many relationships between process variables and raw materials are either complex or unknown.
3. Many quality targets are difficult to express as process variables i.e. printability or runnability of paper.
4. Laboratory measurements are often unsuitable for control because off-line tests cannot be performed frequently, and they are often expensive and inaccurate.

2.3 Enhanced Computer Control

Process simulation can greatly enhance process control (12). Addition of a PAT simulation model to a mill control system would also enhance the utility of existing control and provide information needed to overcome the above obstacles. The model would also provide a means of linking in new sensors which indirectly measure key end-use performance variables such as the sonic velocity sensor developed at IPC or the lignin sensor now under development.

2.4 Substitution of Lower Energy (Cost) Furnishes

Typical newsprint production consists of 74% high yield mechanical pulp (TMP or Groundwood) and 26% kraft. However, many newsprint machines use considerably more kraft, e.g. 34%, because of a perception that runnability will deteriorate with the higher mechanical pulp levels. The increase in energy consumption due to the 7% higher kraft use is $5.80 \times 10^{**5}$ Btu/ton. For a production of 290 ton/day, this amounts to $1.68 \times 10^{**8}$ Btu/day in energy savings. If

half of the newsprint paper machines operated in a similar manner, the total energy savings for newsprint by this change alone could be 1.39×10^{12} Btu based on the 1974 production of 4,800,000 tons.

Other grades such as printing papers, packaging, tissue, and liner-board also use mixtures of kraft and somewhat lower energy furnishes such as mechanical pulps, sulfite, and wastepaper. Similar tradeoffs could be made to further increase the ratio of the lower energy components without adversely affecting runnability or end-use performance by the use of a computer simulation capable of predicting product quality.

An increase in the substitution of waste (secondary) fiber for virgin fiber at the paper machine will also reduce overall energy requirements (13). It is estimated that the production of recycled newsprint from deinked waste newspapers would consume about 19.5×10^6 Btu/ton compared to 21.95×10^6 Btu/ton for virgin fiber resulting in a 7% reduction of energy use.

However, when the energy content of the virgin fiber supplied to the machine is considered, the energy consumption for virgin fibers increases to 28.1×10^6 Btu. On this basis, the recycled deinked fibers could result in a 31% reduction in gross energy consumption. The primary drawbacks in use of recycled fibers, such as contaminants removal and property degradation, can be at least partially eliminated by the use of process simulation, performance attributes, and pilot experimentation techniques. If use of recycle newsprint were increased by only 1% through use of these techniques, the payoff in energy savings would be .31% of gross energy consumption or 0.41×10^{12} Btu/yr.

2.5 Reduced Waste

Final paper properties are often achieved in the converting step. Converting waste is usually recycled back to the paper mill. For corrugated

containers, this waste is typically 9.7% (10 p. 92). Since the recycled paper must be reconstituted and reconverted, this increases the energy consumption by about 10% for both mills. Assuming that converting waste consists mainly of breaks and off-spec product, both of which could be reduced by the application of computer technology, there are considerable potential benefits to be derived in this area.

Approximately 6% of the 320 billion square feet (22.4 million tons) of corrugated board produced in the US each year is lost as waste. Much of the waste results from poor bonding of the liners to the fluted medium, to high-lows, flute fracture, and to strength loss during fluting. Warping of the corrugated sheets also reduces productivity in printing operations and contributes to waste. One study notes that box plant managers list bonding as the number one problem (14).

According to The Technical Association of Pulp and Paper Industries (TAPPI), a 1% reduction in waste can result in a savings of \$80,000 per 20,000 tons production based on a current price of \$400/ton. Over the entire industry, the savings could exceed \$80 million/year per % reduction in waste. The above reduction of 1% in waste corresponds to an energy savings of 90,000 BBL of oil/year.

2.6 Improved Design

Design of new papermachine and pulp mill installations would be greatly improved through the use of process simulation technology using PATs. Often design and construction is completed before the grade structure for the mill is determined. The shakedown period to actually determine the detailed grade structure for a mill can result in delays and considerable readjustment in the grade production through the entire corporate system. In addition, production is also lost due to grade swings, machine breaks, and downtime.

No statistics are available on the effects of design and startup of greenfield mills on energy consumption patterns, but a conservative estimate of the production losses would be 1-2% for the industry per year. Improved design procedures could reduce lost production by 10-20% or .1-.2% of production, equivalent to approximately 2.62×10^{12} Btu/yr.

3. BACKGROUND

3.1 Property Development During Papermaking

Paper manufacture begins with chips from one or more species and ends with dozens of grades with hundreds of different end-use performance characteristics or specifications. During these manufacturing processes, the fibers are separated, processed to enhance their bonding potential, formed into sheets, pressed to consolidate the web and remove water, dried, and passed through a variety of converting operations to achieve the desired properties.

Conventional process simulation techniques treat this process as a flow of mass and energy without consideration of processing stages on the paper-making potential of the fibers. Fibers are viewed simply as lumped components of cellulose and lignin or as generic fibers. Neither the structure of the fibers nor the network is represented. Important interactions between fiber or network properties and mass and energy balances -- particularly in sheet forming and dewatering -- are also impossible to represent with conventional approaches.

A considerable body of knowledge has been developed relating characteristics of fibers and the developing network with the final sheet properties. Until recently, this information was underutilized in general and totally ignored in the areas of process simulation and modeling.

Early work by a committee of TAPPI showed that sheet properties could be related to a handful of fiber variables (13). Similar conclusions have been

drawn by many others (19,23,24) as well as by studies at IPC (16,42,43). The committee developed linear programming models that relate wood properties and specific papermaking conditions to kraft pulp and papermaking properties for linerboard and multi-ply sack grades. With these models, the committee determined ranges of desirable traits for several species of trees to improve forest genetics programs.

The TAPPI committee report concluded that "Underlying the whole problem of predicting sheet properties from wood properties is the need for a unifying theory of sheet formation and sheet strength. This area is receiving considerable attention ... and appears to be an extremely promising area of research which can provide a mathematical structure and quantitative data for models such as those developed in this study."

Since that time, the works of Cox, Van den Akker, Page, Nissan, Baum, Habeger, Whitsitt, and many others have established a sound theoretical framework of the structure of paper and models for many sheet properties (17-26, 28-37). Relevant areas of fiber and sheet structure, optical properties, and process effects have also been extensively reviewed (22,23).

Others have contributed knowledge on the wide variety of factors which influence fiber and network properties such as species, sheet forming, wet consolidation, stretch and orientation, and pulping (27,38,39). Others have helped to define key performance attributes (40,41).

MAPPS is a process simulation program developed by the Institute and now widely used throughout the pulp and paper industry and by academic programs in pulp and paper technology. MAPPS enables the user to simulate most paper-making processes from the pulp mill to the power plant. By providing detailed steady state mass and energy balance information, MAPPS can be used for engi-

neering design, troubleshooting, debottlenecking, and performing what-if studies for process improvement. Work is underway to add a dynamic feature to MAPPS to provide information for process control and training.

The MAPPS PAT system now provides the means of linking these more fundamental models for sheet properties with basic fiber and network properties and processing conditions.

As shown in Figure 1, performance attributes (PAT's) are fundamental variables of the fibers and network which link raw materials and processing conditions (process attributes, X's) to various measures of end-use performance (PROP's).

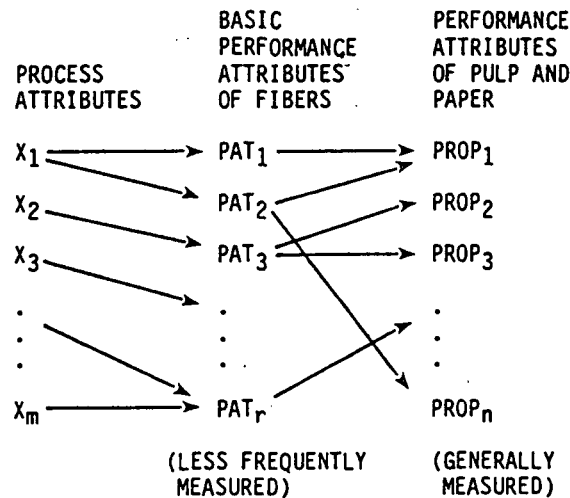


Figure 1. Performance attribute structure.

Figure 2 illustrates the interactions between mass and energy balance models, PAT models, and property models. The models are input-output in nature so the mass and energy flows and fiber attributes leaving a processing step are changed depending on the characteristics of the processing step. Attributes of the entering and leaving streams, along with material flow information, are used to determine properties of the streams entering and leaving each operation block.

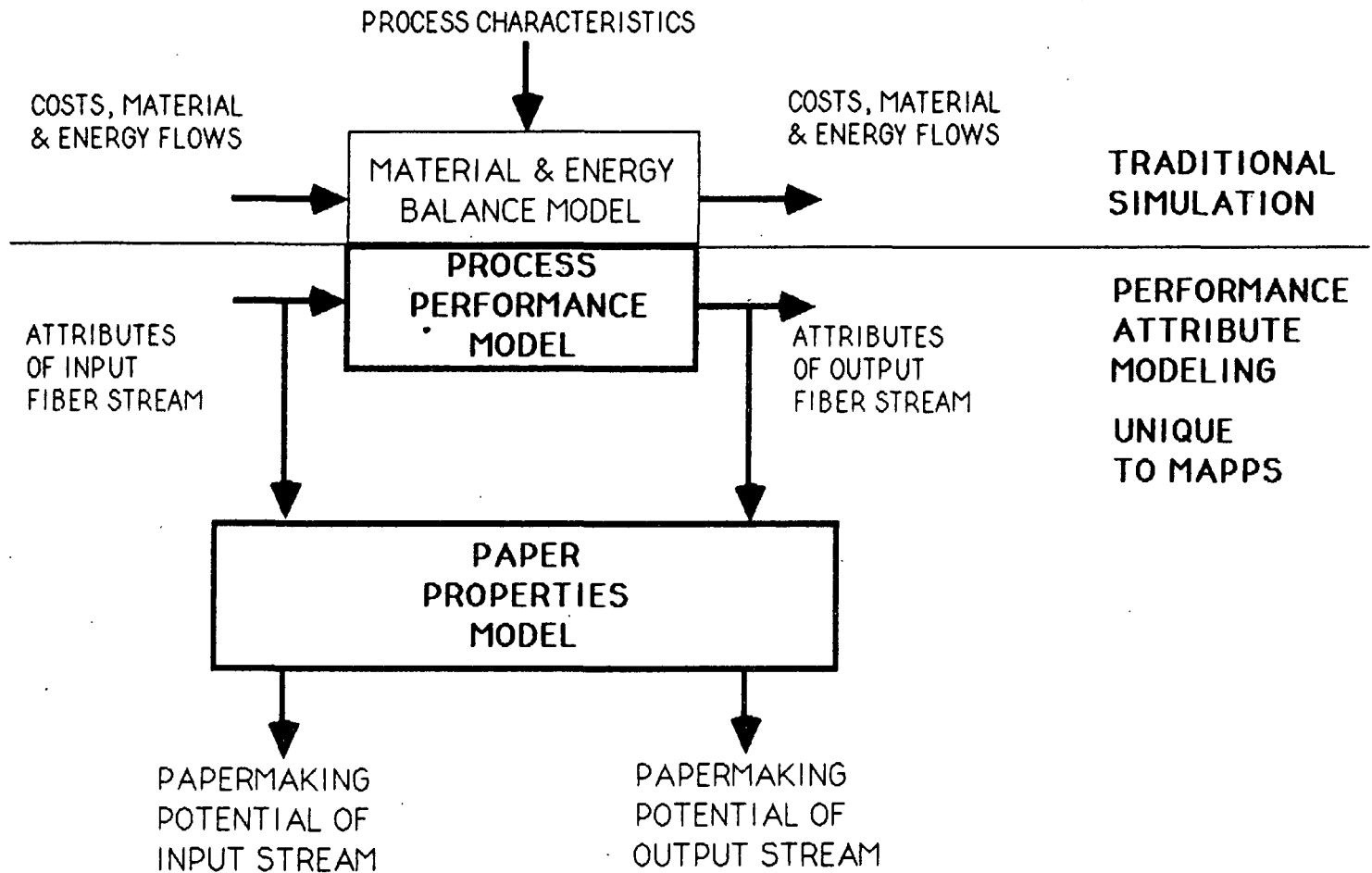


Figure 2

A process model such as that shown in Figure 3 for high-yield pulping is assembled to simulate a particular process. Simulation with the process model then provides information on the development of properties and attributes throughout the process as illustrated in Figure 4.

HIGH YIELD PULPING PROCESS

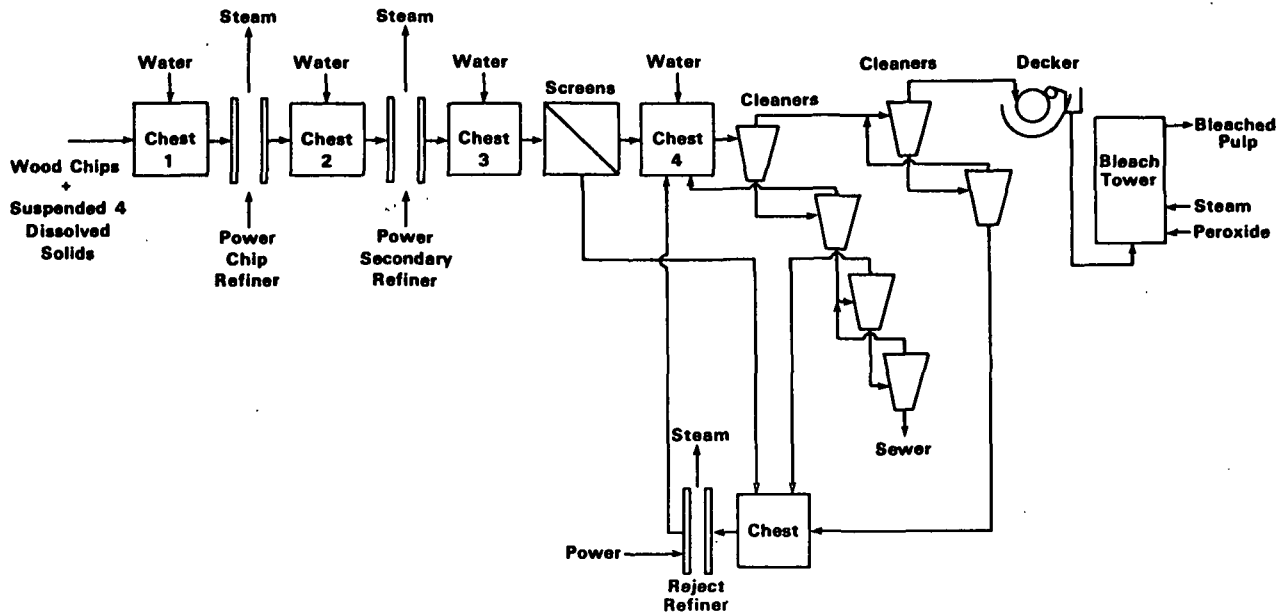


Figure 3

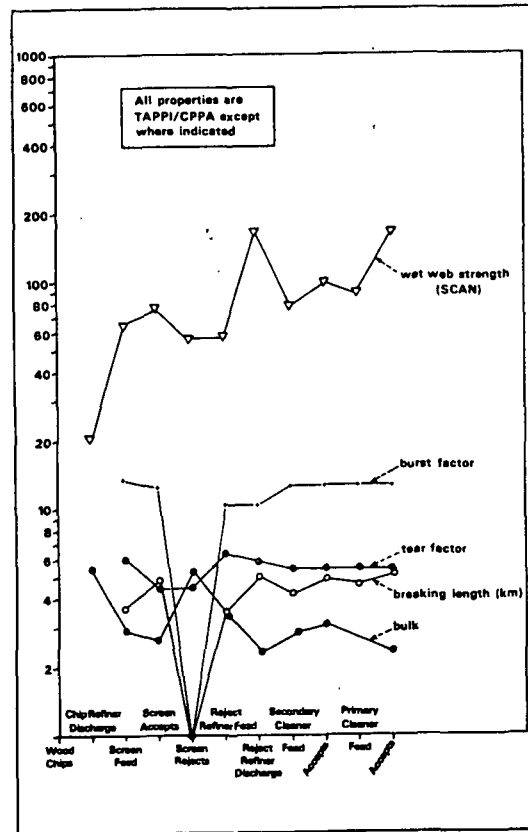


Figure 4

To be useful, the PAT system must account for a wide range of factors which influence end-use properties. Among the many factors are species, pulping, screening, cleaning, bleaching, additives, sheet forming, wet stretching, wet pressing, drying, calendering, and repulping. The PAT system accounts for species through the use of a species data base. The remaining factors are accounted for through models of the effect of each process on each performance attribute. These effects are summarized in the following sections.

3.2 Performance Attributes

This section provides an overview of performance attributes and how they are affected by various processing conditions.

Fiber Shape

Fiber shape or morphology is represented by fiber length and width distributions and cell wall thickness. Each distribution is represented by the average and the standard deviation. A third parameter defines the type of distribution, i.e. log-normal, normal or Weibull. By combining the distribution functions into a correlation matrix, it is possible to represent all combinations of length and width. Each portion of the correlation matrix is assigned to a specific fiber category which is frequently measured with screens as shown in Figure 5. DL and DW refer to the distribution functions of length and width respectively.

Mapping of 100 Internal Fiber Types to 9 Fiber Stream Components

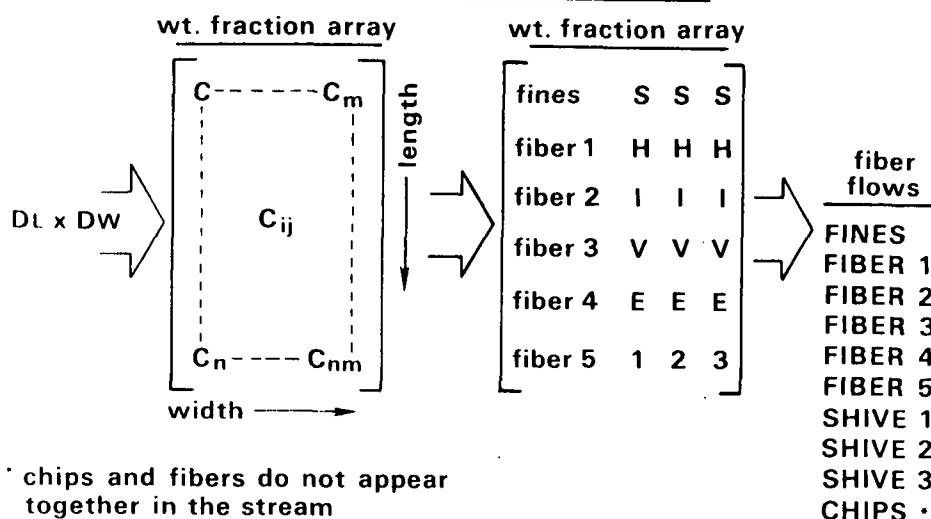


Figure 5

These attributes are first defined for each species in their native state through a species data base. The fiber length and width distributions are shifted by various operations such as refining, screening, cleaning, and papermaking.

Composition

Fibers consist of alpha-cellulose, amorphous or hemi-celluloses, lignin, extractives, and ash. However, for convenience, the attributes used to represent fiber composition are yield, kappa number, and the ratio of hemi-cellulose to total cellulose. Kappa number is the result of a test which is linearly related to lignin content. With these variables it is possible to determine the actual fiber composition assuming extractives have been removed. Initial values are provided by the species data base.

These three attributes account for many of the primary effects of pulping. Other effects are discussed in the section on pulping.

Fiber Physical Properties

Important physical properties are fiber density, tensile strength, and tensile modulus. These intrinsic properties of the fibers are not easily measured, but they are extremely influential in determining final sheet properties. These values are also initialized by the species data base.

Fiber Surface Area

Due to the fibrillar structure of wood fibers, the actual external surface area is generally larger than would be expected for smooth cylinders. External surface area is developed by refining, and is a critical step in paper-making. The first attribute in this category is Canadian Standard Freeness, CSF, which is a direct measure of external surface area.

The second attribute is the K-factor which represents the effect of refining. For a given fiber length distribution and K-factor, it is possible to compute the hydrodynamic specific surface area. A second relationship relates CSF to hydrodynamic specific surface.

The two important effects of refining, fiber separation, and surface area development, are accounted for through the use of fiber distribution parameters, K-factor, and CSF. Other effects, such as swelling and increase in fiber flexibility and bonding potential, are accounted for by other factors discussed later.

Optical Properties

The light absorption coefficient is an inherent characteristic of the lignin color bodies in the fiber. This attribute is influenced by lignin removal steps such as pulping and bleaching. A second factor, light scattering, can be predicted from other sheet characteristics. Sheet brightness, an important end-use performance characteristic of many grades, can then be predicted through use of the Kubelka-Munk theory.

Brightness development is accomplished through various types of bleaching operations. Bleaching can also have other beneficial effects on other properties through the removal of lignin. The three attributes, yield, kappa, and absorption coefficient can be used to account for the main effects of bleaching.

Fiber Stiffness Factor

An attribute of fibers which contributes significantly to bonding potential is fiber compliance or bending stiffness. Fiber stiffness in general tends to increase with increasing cell wall thickness, increasing yield (more lignin present), and decreased degree of refining (less swelling or removal of the outer most layer of the fiber).

These factors are already accounted for through three attributes previously mentioned. However, these factors do not account for the effects of drying the fibers. When fibers are dried, they become stiffer. Some fiber fractions do not rewet and return to their predried condition. This effect, sometimes referred to as hornification, is important in the simulation of fiber repulping and secondary fiber use. This is accounted for by a fiber stiffness factor which increases when the fibers are dried above a critical level (93%). Upon refining or bleaching, this factor is restored to one to qualitatively simulate the restoration of fiber flexibility to its predried state.

Network Formation

Once the fibers have been separated and their surface area developed through refining, the stage is set for network formation. The sheet forming process, such as the Fourdrinier, handsheet former or twin wire former, has as its major functions the formation of a mat of fibers and the separation of as

much water as possible. Inevitably, much of the fine fibers and suspended material pass with the water. Thus the sheet that is eventually formed contains a different fiber makeup than that entering the process.

Also the fiber laydown mechanism of each forming process imparts a variability to the network called anisotropy. Typically, fibers will be preferentially oriented in the machine direction and more fines will be present in the center and top of the sheet than near the drainage wire.

Sheet Anisotropy

Variability Through the Thickness of the Sheet and Sidedness

The variability throughout the thickness of the sheet, referred to as Z-D variability, is accounted for by the use of the fiber morphology and surface area attributes. As each layer of the sheet is formed, this information is stored in the Z-D variability array. Each row of the array contains attributes for each layer in the network.

As a result of Z-D variability and the imprint of the wire on the bottom surface, the network also has another undesirable characteristic, sidedness, which often must be reduced later through calendering. Sidedness is accounted for by referencing the first and last rows of the Z-D variability array in the property calculations. The wire imprint, wire mark, is not as yet accounted for. The sidedness is represented by the potential bonded areas of the top and bottom of the sheet. These variables are discussed further in a later section.

Fiber Orientation and Wet Straining

Fiber orientation is represented by an orientation ratio which is the tangent of the average fiber angle of orientation relative to the machine direction.

A second contribution to anisotropy is wet straining of the sheet near the end of the wire and in the drier section. Like fiber orientation, stretch also imparts preferential orientation in the machine M-D direction. The effect of stretch is represented by the stretch factor. Together the orientation and stretch factors influence the directional properties of the sheet. This means that many sheet properties are not isotropic (invariant with direction), but vary in the three principal directions, M-D, C-D (cross machine), and Z-D (thickness).

Formation

Another important aspect of forming which is also related to sheet anisotropy is called formation. Formation relates to the spatial variation (mainly M-D and C-D) in the distribution of fibers. This may be quantified as a variation in sheet basis weight and caliper, or more simply as a variation in sheet density.

The formation factor is determined by the forming conditions and the characteristics of the stock (particularly fiber length and freeness). Fundamentally, formation is related to floc formation and breakup in the turbulence fields of the flowing stock. Modeling at this level is beyond the scope of this work.

Practically, the formation factor influences the properties of the sheet. Poor formation leads to poor tensile properties as well as a poor visual appearance. Formation effects distinguish handsheets from machine-made paper. Further, achieving good formation is a critical problem for high speed paper machines while good formation is the norm on slow speed machines and molds.

Differences in formation between handsheets and machine paper make the prediction of machine paper properties from handsheets a difficult task. Direct prediction of machine paper quality would, therefore, be very beneficial.

One of the key theoretical assumptions of the PAT system is that formation not only affects the physical density distribution of the fibers, but also affects the bond density. In fact, the two are assumed to be identical for a dry sheet.

The formation factor is assumed to represent the coefficient of variation or efficiency of bond formation. Low density areas represent areas of low bond density. The converse is true of high density areas. Because the ultimate strength of the network is governed by the weakest members, the effective bond density is reduced as the formation index drops below its ideal value of 1.

In summary, the five attributes which are generated in the forming step are the potential bonded areas of the top and bottom sides, the formation factor, orientation ratio, and wet stretch factor.

Generation of Optical Contact (Wet Pressing)

Wet pressing serves two primary purposes, to remove water from the sheet and to consolidate the network. Pressure on the web within the press nip as shown in Figure 6 forces fibers into close contact. This compressibility effect brings the fibers into optical contact and increases the potential bonding in the sheet. The effect depends on the peak pressure, fiber flexibility, and entering potential bonded area. Fiber flexibility tends to increase with decreasing fiber cell wall thickness, decreasing yield (removal of stiff lignin), and increased refining (decreasing freeness).

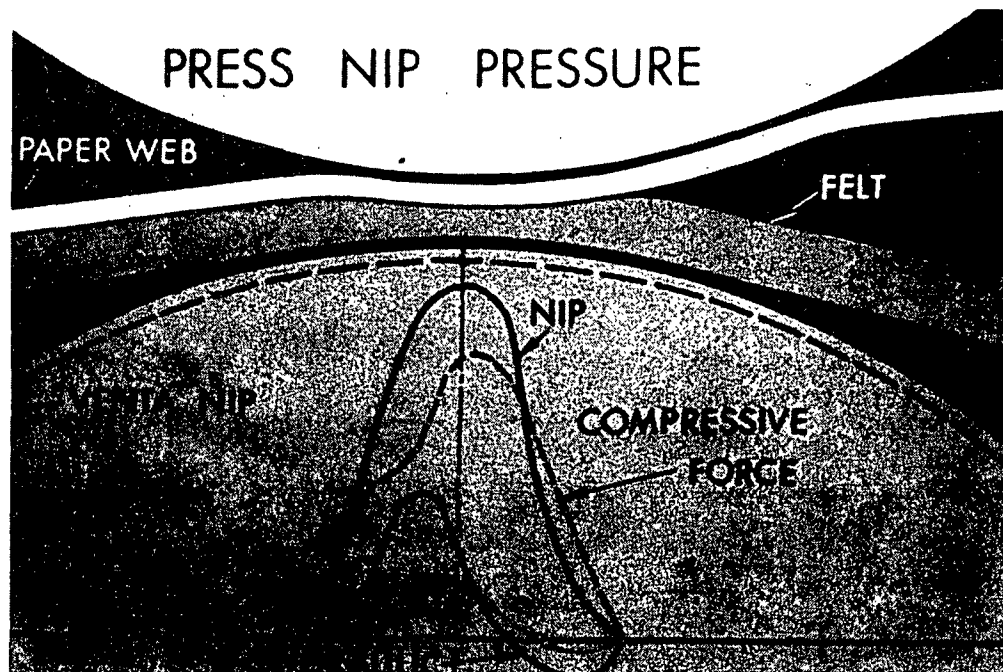


Figure 6. Roll press and pressure diagrams

No new attributes are needed to model wet pressing. Instead, the potential bonded areas of the top and bottom increase depending on the compressibility of the top and bottom layers of the sheet. Thus Z-D anisotropy generated during forming is accentuated in the pressing process. The compressibility is a function of other attributes such as CSF, yield, and cell wall thickness.

Generation of Hydrogen Bonding (Drying)

Drying also has two primary functions, to increase solids content to 93% or higher and to form hydrogen bonds which create the strength of the network. As the sheet dries, areas in optical contact are converted to actual bonded area depending on the degree of moisture removal and the temperature level. Other important effects such as preferential strain in the machine direction due to lack of restraint in the control direction can lead to undesirable effects such as curl.

The significant attribute in drying is therefore the actual bonded area, S_a . This is assumed to be the average of the top and bottom of the sheet. S_a plays a crucial role in determining sheet bulk density and bond density. The former affects optical properties such as scattering coefficient while the latter affects tensile properties such as modulus, breaking length, and burst factor.

As the fiber dries, the cellulose matrix tends to collapse resulting in an increase in tensile and bending modulus (stiffness). This results in an apparent drop in the bonding potential of dried fibers. Some describe this effect as hornification of the fibers. When dried fibers are repulped, they tend to form bulkier, weaker sheets unless they are rerefined or pass through chemical treatments which open up the cellulose structure again. In order to simulate this stiffening effect, the fiber stiffness attribute is increased in the dryer in proportion to the amount of fiber drying.

Alteration of the Sheet Structure and Inter-fiber Bonds

The sheet structure can be altered in a variety of ways during paper-making. Strength or retention aides can be added before the sheet is formed to alter fiber bonding or fines content. Fillers can be added to increase opacity by occupying space between fibers. Coatings are applied to alter sheet surface properties. Multiple sheets are formed to produce a composite structure with unique properties. At the present time, these effects are outside the scope of the PAT system, but they could be added at a later date.

In addition to the above-mentioned processes, sheet properties can be altered through converting operations. Calendering represents the most common and important converting process. Different calendering methods are used depending on the grade and forming method.

Ideally, calendering is designed to remove sidedness and generate a smooth printable sheet surface without adversely affecting bonding, sheet strength, or reducing sheet bulk. Unfortunately, the application of pressure in the calender nip increases contact between fibers. However, unless moisture and temperature levels are high enough to soften the fibers and allow for hydrogen bond formation, the densification process usually results in bond breakage and strength loss. The increase in fiber contact does tend to increase surface smoothness. By applying different treatments to each side, it is possible to reduce sidedness.

No new attributes are generated in the calendering step. Instead several key attributes such as actual and potential bonded areas are affected by moisture, temperature, and pressure. These in turn affect sheet properties.

3.3 Overview of Unit Operations

Most of the mass and energy transport inherent in papermaking alter one or more performance attributes. Conversely, in several important cases, the mass and energy performance of an operation is influenced by a performance attribute.

Wood Species

The process is assumed to begin at the wood pile with chips of a given species. The characteristics of the fiber in the chips entering the pulping process are supplied by a special block initializes the flows of components and attributes by accessing a species data base.

Pulping

Chemical Pulping

The primary purpose of pulping is the breakdown of the fiber chips into bundles and then individual fibers. Chemical pulping dissolves lignin and

most of the amorphous celluloses resulting in a very pliable fiber bundle which is easily separated in low consistency refining. Chemical pulping reduces yield significantly. However, it also makes the fiber more pliable and wettable, and leads to higher bonding potential. Dissolution of lignin and cellulose occurs in the digester. Fiber separation usually takes place in a low consistency refiner following the discharge.

Chemical pulping reduces yield, kappa, and the hemicellulose ratio. Changes in these attributes affect sheet consolidation and other operations downstream. The yield loss is compensated for by energy recovered by burning black liquor from the pulping step. The recovery process simultaneously generates a significant portion of the energy requirements of the process while regenerating pulping chemicals.

High Yield Pulping

Mechanical pulping (high yield) relies on combinations of mechanical action, heat, and some mild chemical pretreatments to separate fibers with very little yield loss. The result is a distribution of fibers, fines, and shives of fiber bundles. Mechanical pulping generates more hydrodynamic specific surface area with corresponding lower freeness than chemical pulping. However, the higher lignin content results in stiffer fibers which do not bond as effectively. Thus while there is more area to bond, the bonding efficiency is lower for mechanical pulps. Chemical pretreatment removes some lignin and shifts the behavior toward that of chemical pulps.

Refining of pulps also increases the intrinsic strength of fibers by opening up the internal structure. This is simulated by an increase in the fiber tensile strength which is related to the surface area developed during refining.

Stock Preparation

Screening and Cleaning

The stock preparation system is designed to remove unwanted material such as shives and debris from the pulp prior to sheet forming. Screening separates longer fibers and bundles from shorter fibers. The accepts or overflow streams tend to have a lower shives (fiber bundle) content. Hydrocyclone cleaners separate on fiber surface area or density. Dirt and heavy debris tend to leave with the underflow while high surface area, high length to diameter ratio, and less dense material leave with the accepts. Rejects are combined and refined in a reject refiner and recycled back to various parts of the stock prep system (see Figure 3).

The stock leaving the system will be lower in shives and higher in fines, and will have a lower average length and width, higher specific surface area, lower freeness, and higher bonding potential area than entering fiber. Performance characteristics of these operations are strongly dependent on fiber attributes.

Blocks which simulate screening, cleaning, refining, and stock mixing generate handsheet properties based on the composition and attributes of the streams entering and leaving each block. This provides information needed for a detailed analysis of the stock prep system for optimal design and reduced energy consumption.

Mixing

Mixing of various stocks occurs frequently throughout the pulping and papermaking process. The PAT system mixes fiber attributes as well as material and energy. Most attributes are blended based on relative mass flows.

Some mixing operations involve reslurrying of the wet or dry sheet. Since reslurrying involves a dissolution of the fiber network, PAT's which represent the network are changed.

Screening and cleaning tend to accentuate differences between attributes. Thus the properties of the accept and reject streams are usually different.

Sheet Forming

The sheet is formed as the dilute fiber slurry impinges on a wire moving at approximately the same speed. Fibers are deposited by a filtration rather than a thickening mechanism. For this reason, a rather dense layer of fibers forms on the wire. The slurry above the forming mat remains at a constant consistency. The white water which drains from the slurry contains fines and suspended material, and is of relatively low consistency (wt fibers/wt slurry).

As the mat forms, the basis weight (mass/area) increases and more of the fine material in the slurry is retained by the forming mat. White water consistency decreases as the mat forms. Beyond the initial gravity drainage zone, drainage is assisted by the application of vacuum through various devices placed beneath the wire. The severity of these assists increases as the mat basis weight increases due to the decrease in mat permeability, increase in pressure drop, and increasing strength of the mat.

The PAT system accounts for many aspects of the forming process including retention, wire and drainage element design, and location. The model includes various filtration resistance functions which account for local turbulence level, sheet basis weight, pulp freeness, and other factors. As mentioned above, the model also accounts for formation effects, fiber orientation and stretch, and Z-D variability in fiber distribution and surface area.

The Sheet Forming model also includes submodels of individual drainage elements, a dandy roll, and the head box.

Sheet Consolidation and Wet Pressing

The Wet Pressing model determines the degree of dewatering and sheet consolidation occurring in a single press nip. The model also computes the press power requirements. Required information includes felt basis weight, sheet basis weight, entering moisture content, press speed, and lineal nip loading (see Figure 6.)

The mass and energy portion of the model uses this information and PAT information, particularly freeness, to compute nip residence time, maximum nip pressure, dewatering time constant, and moisture removal. The performance attribute portion computes the sheet compressibility and the increase in potential bonded area resulting from pressing.

Drying

MAPPS contains a detailed and reliable mass and energy balance model of the drier section. The PAT system simply adds submodels for several PAT's based on the amount of moisture removed during drying. These effects were discussed in an earlier section on sheet bonding.

Calendering

Although calendering is not a major consumer of energy, its effects on final sheet properties is significant. The calendering model consists of several submodels to compute densification, heat transfer, and property effects. The heat transfer submodel determines heat exchange between the sheet and the roll in the nip and over the roll surface.

Sheet densification depends on nip loading (lineal nip pressure), speed differential between sheet and roll, sheet temperature, and sheet moisture. Bonding or debonding of the network may occur depending on the moisture and temperature of the sheet as it passes through the nip.

Each side of the sheet is affected differently due to the Z-D variation in network attributes. Gloss and surface roughness, important printing properties, are computed. In addition, tensile properties are affected by the degree of bonding or debonding which occurs in the nip. This spectrum of effects makes it possible to simulate various types of calendering.

Bleaching

The main purpose of bleaching is to dissolve color bodies located mainly in the residual lignin. By removing these light-absorbing bodies, the fibers are brightened. The main effect of bleaching is therefore a reduction in the light absorption coefficient, a performance attribute. Dissolution of the color bodies usually leads to a removal of much of the residual lignin resulting in a reduction in kappa number, another performance attribute.

Severe bleaching conditions and bleaching in oxygen can also oxidize some cellulose or hemicellulose resulting in a reduction in yield, a third attribute. Bleaching in hydrogen peroxide dissolves color bodies without actual removal of lignin. Peroxide is widely used with high yield pulps to brighten while preserving yield.

Another important result of bleaching is a softening of the fibers resulting mainly from the removal of lignin. The softening is probably most pronounced for previously dried fibers. Therefore, the fiber stiffness coefficient is reduced to 1 in any bleaching stage. This restores the fiber to its natural predried stiffness.

The system has a number of blocks which handle a wide variety of bleaching processes. Specifically bleaching with chlorine, chlorine dioxide, hydrogen peroxide, oxygen, and alkaline extraction with or without oxygen assist are handled. In addition, a generic bleaching module is available to handle other bleaching operations.

Property Utility Blocks

The system contains many other important blocks which perform a variety of functions. Perhaps the most important of these is PROPS, a block which computes 25 handsheet and machine-made paper properties at any location in the process.

Other Unit Operations

The MAPPS system contains many other blocks whose main purpose is computation of mass and energy balances. Many of these are in the areas of chemical recovery and steam and power systems and are essential for a complete simulation and prediction of energy impacts.

3.4 Optimization

MAPPS also contains an optimization feature which will provide estimates of optimal conditions given constraints and an objective function.

3.5 Sheet Properties (End-Use Performance Specifications)

There are hundreds of important sheet properties or specifications depending on the grade and intended end-use. A few important properties computed by the system are discussed below. Properties can be divided into general categories such as physical properties, tensile properties, surface or printing properties, and optical properties. Tensile properties can be subdivided into destructive and non-destructive.

Sheet density is one of the key properties which influences most other properties and as such could be considered a primary property. As mentioned above, sheet density is strongly related to the fiber optical contact and to potential bonded area. In most situations where fiber bonding potential is realized, sheet density is an excellent measure of interfiber bond density.

Since network strength is related to a combination of fiber strength and bond strength, sheet density is usually a controlling variable except at very high degrees of bonding where fiber tensile controls. However, there are several situations in which fibers are brought closer together and yet the strength is low. For this reason, the PAT system defines a separate attribute for actual bonded area which influences strength and potential bonded area which influences sheet density and certain optical properties. The two are linked in the drying step where hydrogen bonds are formed in the presence of moisture and temperature. They are also linked in the calendering step where high densification conditions may destroy bonds especially when applied at low temperature and moisture.

Conversely, high moisture conditions also weaken bonds resulting in strength loss without significant reduction in sheet density. Ultimately when enough moisture is added to the sheet, the network breaks up and all strength is lost. The actual bonded area drops to zero. The potential bonded area also drops due to the physical separation of the network.

In addition, there is some loss of external surface area and some stiffening of the fibers in the drying step which reduces the bondability of the fibers. This reduces the sheet forming characteristics of repulped fibers.

While a detailed discussion of the basis for the various property models is not practical here, some of the interactions predicted by the models

for two important properties, density, burst and tear, are shown in Figures 7 through 9.

Figure 7 shows that sheet density increases with wet pressing pressure and refining (decreasing CSF). The response to refining or pressing is different at various levels of the other. The effects of multiple repulping is shown by comparing lines marked virgin fibers (zero repulping) with lines marked six repulpings. Repulping tends to stiffen fibers which reduces sheet density at normal pressures of 60 psi, but leads to a small increase at zero pressure and low refining levels (500-600 CSF).

The effects of repulping are similar to those seen between fibers of different wall thicknesses. Thus the differences shown between virgin fiber and six repulping mimic the differences between or within species of different fiber wall thickness. Although not shown in the Figures, increasing yield from 47% to 100% shifts the lines downward and increases the response to pressure and freeness.

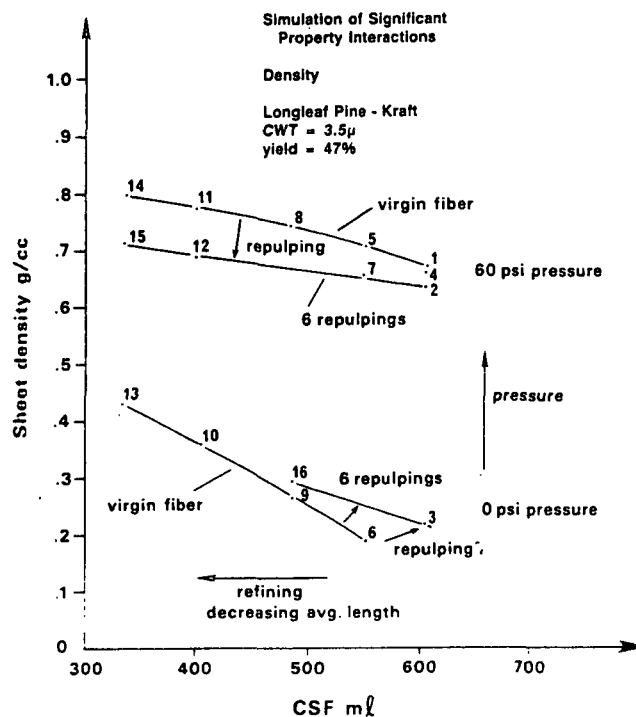


Figure 7

Figure 8 shows the response of burst factor to density for various levels of pressure and repulping. Increased refining and pressure leads to an increase in burst and the response to each varies with the other. Repulping tends to reduce burst, as it does with most tensile properties. However, the effects of repulping on burst can be partially overcome by refining and pressing.

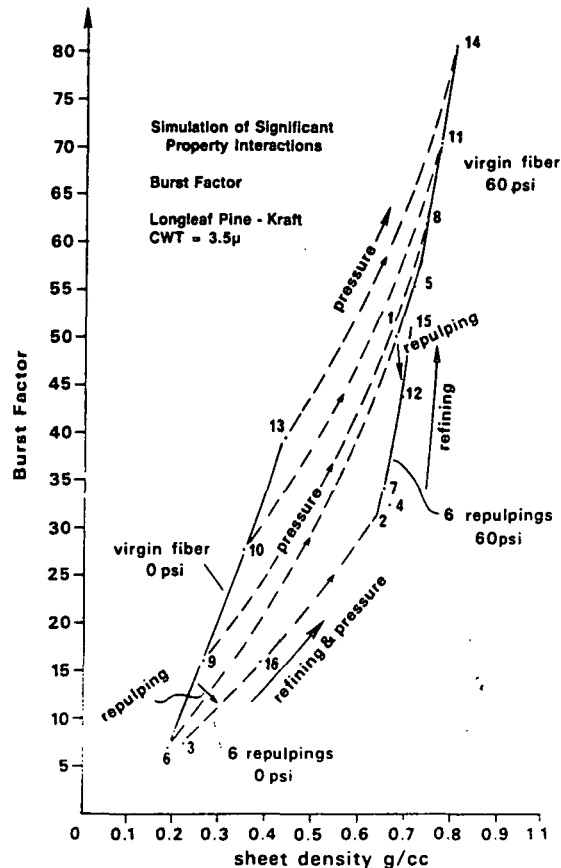


Figure 8

Figure 9 shows tear factor which tends to respond in the opposite direction to burst factor. However, tear is also more dependent on fiber length than either density or burst. Thus as refining increases, fiber length tends to decrease and this is detrimental to tear factor. Tear is not very sensitive to pressure, but is highly sensitive to refining. The effect of repulping varies significantly with pressure, however. At low pressure, repulping tends to decrease tear, while at higher pressure, repulping tends to increase tear. Overall, the responses to these variables is the mirror image of those for burst.

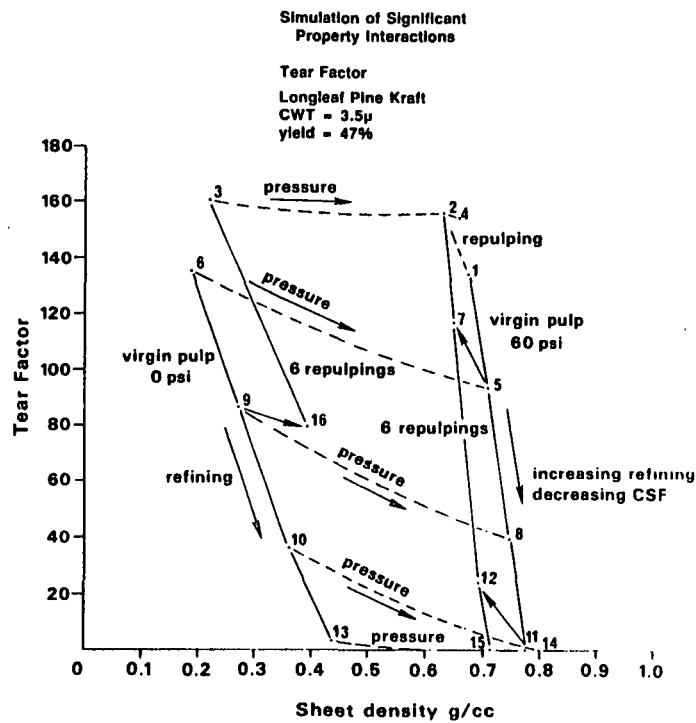


Figure 9

4. PROJECT PLAN

4.1 Basic Premise:

The underlying premise of this proposal is that the quality and cost of products produced in a specified mill from available raw materials can be predicted accurately with PAT models. This capability has already been demonstrated by preliminary IPC work (16,42,43).

4.2 Objectives

The objective of the proposed research is to develop and use quality models to improve the performance of products produced in domestic pulp and paper mills. The net result of this improvement will be a reduction in energy consumption through the application of quality models.

4.3 Work Plan Summary

Mill Case Studies

The centerpiece of the project will be two mill case studies. These will involve detailed simulation of two mills producing representative grades which are sufficiently different to validate different aspects of the Performance Attribute Model. The two targeted grades are newsprint and linerboard. The case studies will serve several purposes: detailed validation of the models, targeting of areas for improvement in the models, and establishing credibility with the potential user community and user requirements.

The case studies will provide detailed analysis of the mechanisms of property development for the existing operation and means of improving or maintaining performance with reduced energy consumption through the use of optimization techniques.

Laboratory Studies

Although the primary activities will involve computer applications, some laboratory work will be needed to generate basic information to improve existing PAT models or to add new PAT models. Some experiments may be used to validate some key assumptions of the model.

Process Control Applications

After a significant portion of the mill cases have been completed, work should begin on the integration of this system into process control and mill information systems in one or more of the case study mills.

Model Development and Expert Systems

Although the bulk of the PAT system is now in place, the modelling development will continue, particularly some aspects of papermaking which will be studied and incorporated into the model. In addition to the addition of

deterministic models for the PAT system, the modelling effort in its later stages may involve development of a small expert system capability to handle the effects of equipment details not easily included in the deterministic models.

The second and perhaps more important portion of the modelling task is the addition of an expert front end (user-friendly interface) to aid the user in constructing a model of his or her process and providing advice about the use of performance attributes.

Publications and Computer Models

The models and case study results will be documented and published in the open literature whenever appropriate. The MAPPS programs and models developed as a result of this project may be licensed from The Institute of Paper Chemistry.

5. RESOURCES

5.1 Timetable and Budget

TABLE III lists major tasks and funding requirements including IPC funding.

TABLE III
RESOURCES REQUIRED

TASK	1987	1988	1989	1990	1991	1992	1993	TOT
MODELING	100	95	70	150	75	75		
LAB EXPTS		50	50	100				
MILL CASE 1			20	75	100	25		
MILL CASE 2				25	75	100	50	
PROCESS CONTROL					50	50	100	
TECH TRANSFER		5	10	15	25	25	10	
IPC (\$000)	100	100	100	100	100	100	60	660
DOE (\$000)				215	275	275	100	865
TOT (\$000)	100	100	100	315	375	375	160	1525

5.2 Computer Resources

The mill case studies and the further development of MAPPS will continue on existing micro-computers. However, the size of the MAPPS PAT system may require development in the UNIX environment. No additional computer facilities will be required.

The expert system components for the system would be developed from commercial shells. There are many ES programs on the market which support integration of fortran programs such as MAPPS.

5.3 Facilities

The project will be conducted at the facilities of The Institute of Paper Chemistry

5.4 Travel

Travel will be required during the mill case study phases to gather information directly from the mill, and to demonstrate the features of the system to mill personnel. Estimated travel costs have been included in the above budget.

5.5 Staff

This project will be carried out in the Engineering Division of The Institute of Paper Chemistry under the direction of Dr. Gary L. Jones, Associate Professor. Dr. James D. Rushton will also participate extensively in the project by providing much of the liason work required to conduct the mill studies. One or more computer support technicians will also be needed to assist with mill model development, PAT system validations, and expert system development and evaluation. Reference information for the major contributors is given below.

Gary L. Jones

Associate Professor, Engineering Division; Senior Research Engineer

B.S., Ph.D. in Chemical Engineering

Background:

Nearly eighteen years experience in the fields of mathematical modeling and process simulation in areas such as bioengineering, polymerization reactors, synthetic fuels, oil reservoirs, and pulp and paper. Extensive experience in reaction engineering of syngas conversion systems, oil shale, coal liquefaction, and petrochemicals. Over three years of research in fiber and paper property development in papermaking.

James D. Rushton

Group Leader, Systems Analysis Group, Engineering Division; Associate Professor of Engineering and Senior Research Engineer

B.S., Ph.D. in Chemical Engineering

Background:

More than 25 years of pulp and paper experience, all heavily weighted toward process applications. Approximately 7 years spent with two pulp and paper producing companies, the remaining time with consulting engineering firms and as an independent consultant. Fifteen years experience in process simulation with numerous publications dealing with process analysis and optimization. Extensive experience in validating millwide simulations of existing pulp and paper making operations.

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STUDENT PAPER CONTEST

sponsored by

**THE INSTITUTE OF PAPER CHEMISTRY
APPLETON, WISCONSIN**

**SUBJECT MATTER: THE USE OF MAPPS FOR PULP AND PAPER
APPLICATIONS**

The Institute of Paper Chemistry has developed a steady state modular simulation program, Modular Analysis of Pulp and Paper Systems (MAPPS), which can be used to simulate any pulp and paper process. It currently is available for use by faculty and students at many academic institutions for educational purposes. If your institution does not have MAPPS and you are interested in entering the contest, have your faculty advisor contact Jim Rushton at the Institute of Paper Chemistry (414/738-3293).

RULES

1. The student must submit a technical paper, suitable for publication, on any aspect of pulp and paper which includes the use of MAPPS. For example,
 - to enhance process design/optimization calculations or designs
 - to provide technical data and information for research and development projects
 - the analysis or critique of any of the existing MAPPS modules or groups of modules
 - programming and documentation of new student-written modules
2. Preparation of the paper shall be in accordance with the Technical Association of the Pulp and Paper Industry's (TAPPI) "Guidelines for Manuscript Preparation."

DEADLINE FOR SUBMITTAL

The deadline for submittal of the paper shall be December 31, 1989.

JUDGING

1. The papers will be judged by a panel consisting of a representative from each of the academic institutions licensed to use MAPPS and one or more representatives from the Tappi Journal.
2. The papers will be judged based on their technical content, readability, and suitability for publication.
3. In the event of a tie, the final winner or winners shall be determined by the Group Leader, Process Modeling and Simulation, at the Institute of Paper Chemistry.

AWARDS

1. Winners will be selected for first, second, and third place awards. Each winner, if qualified, will receive a full scholarship to the Graduate School of the Institute of Paper Chemistry.
2. Cash awards, as follows, will also be presented to the winners:

First Place - \$ 300
Second Place - \$ 200
Third Place - \$ 100
3. The winning paper will be published in the TAPPI Journal. Other papers judged worthy for publication by the panel of judges will also be considered for publication by the Journal.

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN THE PULP AND PAPER INDUSTRY

The goal of artificial intelligence (AI), as postulated by Allan M. Turing more than 30 years ago, is the creation of a computing system that cannot be discernable from a human being by normal language processing. Artificial intelligence encompasses such subjects as natural language processing, image analysis, robotics, neural networks, and expert systems. AI techniques allow the construction of a program in which each aspect of the program represents a highly independent and identifiable step toward the solution of a problem or a set of problems. In effect, each step could be a representation of information stored in a human's brain and, as with the human brain, if the information is disputed, the program automatically adjusts its thinking to accommodate a new set of facts. AI programming differs from other programming languages in that each minute piece of information can be modified without affecting the structure of the entire program. Thus, an AI program can be more efficient and understandable, i. e. intelligent.

Although the in-depth codification of all the subtleties of AI is not yet possible, much progress has been made, particularly in the area of expert system development. An expert system is a computer program that uses the knowledge of "experts" to solve many types of problems,, i. e. interpretive, predictive, diagnostic, design, planning, monitoring, debugging, repair, instructive, and controlling. Expert systems have the ability to "converse" with the user in his natural language, offering the user expert assistance with his problems when human experts are not available.

The goal of an expert system developer is to analyze the framework of heuristics (rules-of thumb) and inference by which human experts utilize their specialized knowledge to solve problems and then distill this expertise into a form that can be utilized by a computer. This artificial framework, which is electrical in nature as opposed to human or organic, is the "shell" which encases the normal operation of a computer and interacts with it. Thus, an expert system is sometimes referred to as a shell and an expert system developer is usually referred to as a "knowledge engineer."

Knowledge Engineers have developed, or are currently working on, many expert system applications in the pulp and paper industry or in industries related to pulp and paper. Some examples are as follows:

- 1) maintenance diagnostic advisor for a research supercalender;
- 2) operations advisor and troubleshooting guide for a supercalendar operation;
- 3) maintenance diagnostic advisor for a power turbine operation;
- 4) diagnostic advisor to identify the source and/or cause of hole defects in paper;
- 5) diagnostic advisor to identify the types of oil, grease, of other dirt present in paper;
- 6) planning and scheduling advisors to assist management in setting up production grade mixes and rates;
- 7) training programs to qualify or re-train operators for complex process operations (such as the chemical recovery boiler);
- 8) troubleshooting and diagnostic advisor to identify problems with process pumps, suggest corrective actions and/or maintenance procedures;
- 9) alarm management advisors for complex process control systems;
- 10) pulp quality advisors to identify and correct process conditions which result in off-spec products;
- 11) quality advisor to solve problems associated with pitch in a paper machine operation;
- 12) advisor for the diagnosis and solution of the customer-related problems of a chemical supplier.

Obviously, many subtle variations of the above applications are possible and there are likely many more specific applications of expert systems within the pulp and paper industry. A survey and document these applications would be of value to the industry.

The subject of applications for neural networks has recently been addressed by the Institute of Advanced Management Sciences in Cincinnati. A number of speakers and system vendors addressed the use of neural networks for the development of image processing system, i. e. vision systems. For instance, a vision system is available (possibly in use) to sort the many possible grades of veneer produced by veneer manufacturing plants. Outside the pulp and paper industry, particularly in automobile assembly plants, vision systems are more common.